BULLETIN

OF THE

Society for the Promotion of Engineering Education

Vol. IV LANCASTER, PA., JUNE, 1914 No. 10

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EDITORIAL.

This Number of the Bulletin practically completes the fourth volume. It is by far the largest number and is remarkable in that it contains practically all of the papers for the annual meeting and would have contained all but for a mis-

understanding as to the date when manuscripts were expected. The papers have been arranged somewhat as they will be taken up at the meeting. In four years the BULLETIN has grown from nothing to a magazine with a circulation approaching two thousand copies. It is now known in educational circles everywhere and enjoys the hearty coöperation of the entire membership. The original plan called for forty-eight pages per month, but it has never been possible to keep the size down to that. This year the average size will be nearly twice the above number of pages. The publication committee hopes that this large number will exert so useful an influence on the discussion at Princeton that the expense and trouble will be justified. It will render unnecessary the reading of extended abstracts of the papers. On account of the space required for the convention papers the usual departments are omitted.

The Princeton Meeting; The Program.—A study of the program printed on a following page will indicate that the papers have been selected so that they fall into natural groups. With the committee reports practically the whole field of technical instruction is covered. The program was planned with a small number of papers so that after allowing the full fifteen minutes for the presentation of an abstract of each a large balance of available time remained. This was equitably divided among the several topics for discussion.

The Princeton Meeting; Other Features.—It is necessary to have papers at a convention, but papers and discussion are not more than half of the meeting. It would be worth while to come to Princeton even if there were no papers just to meet the one hundred and ninety-nine or so other teachers, engineers, deans and presidents. And Princeton is a delightful setting for the meeting. The historic surroundings, the handsome buildings, the scholastic atmosphere are worth a long trip. Then the golf links, the lake, the tennis courts and the gymnasium swimming pool after the game, are worth considering too.

THE CONVENTION PROGRAM.

TUESDAY, JUNE 23.

12:00 M., Preliminary meeting of Council. 2:30 P. M., Opening session. Address of Welcome, by President John G. Hibben; Response, by Dean Gardner C. Anthony; Business Session—Reports of Officers; Reports of Standing Committees; Committee on Entrance Requiremnts, Prof. J. J. Flather, University of Minnesota; Committee on Statistics, Prof. A. J. Wood, Pennsylvania State College; Report of Joint Committee of Engineering Education, Mr. Desmond Fitgerald, Brookline, Mass. 4:00 P. M., Meeting of the Delegates of the Institutional Members, Prof. Henry S. Jacoby, presiding. 5:00 P. M., Reception by President and Mrs. Hibben at the President's house. 8:00 P. M., Informal Get-together Smoker at the Nassau Club.

WEDNESDAY, JUNE 24.

9:00 A. M., Council meeting. 9:30 A. M., Address, by Hon. Jas. F. Fielder, Governor of the State of New Jersey; Response, by Dean G. C. Anthony; *Session on College Administration*, Dean F. L. Bishop presiding; Address, "The Financial Department of a School or University," by T. H. B. McKnight, treasurer of the Pennsylvania Lines, west of Pittsburgh; Paper, "The Relation of the Administrative Department to the Teacher," by Dr. C. R. Mann, University of Chicago; Report of the Committee on College Administration; Discussion. 12:30 P. M., Adjournment. 2:00 P. M., Paper, "Education in Scientific Management" (June BULLETIN), by Prof. Hugo Diemer, Pennsylvania State College; Discussion. 2:30 P. M., Paper, "Academic Efficiency" (April BULLETIN), by Prof. L. M. Passano, Massachusetts Institute of Technology; Discussion. 3:00 P. M., Reports of Committees on Improvement in Laboratory Instruction; Electrical Engineering, Prof. Chas. F. Scott, Yale University; Materials, Prof. F. P. McKibben, Lehigh University; Mechanical Engineering, Prof. A. M. Greene, Rensselaer Polytechnic Institute; Mining Engineering, Prof. F. W. Sperr, Michigan College of Mines; Report of Committee on Teaching Mechanics to Engineering Students, Prof. E. R. Maurer, University of Wisconsin; Report of Committee on Teaching Physics to Engineering Students, Prof. D. C. Miller, Case School of Applied Science. 4:30 P. M., Adjournment. 8:00 P. M., Lecture, "The Meteor Crater in Arizona," Dean W. F. Magie, Princeton University.

THURSDAY, JUNE 25.

9:00 A. M., Council meeting. 9:30 A. M., *Papers on Fundamentals in Mathematics* (June BULLETIN): "Practical Mathematics," by Profs. W. S. Franklin, Barry MacNutt and R. L. Charles; "The Calculus Without Symbols," by Prof. E. R. Hedrick, University of Missouri; "The Use of the Differential in Calculus," by Prof. E. V. Huntington, Harvard Uni-

versity; Discussion. 10:45 A. M., *Papers on Methods of Study:* "The Preceptorial System and Electrical Engineering at Union College" (June BULLETIN), by Prof. W. L. Upson, Union College; "Teaching Engineers How to Study" (May BULLETIN), by Prof. Geo. L. Sullivan; "Giving Instruction in Methods of Study," by Prof. W. H. Kenerson, Brown University; Discussion. 12:30 P. M., Adjournment. 2:00 P. M., *Papers on Courses of Instruction* (June BULLETIN): "Coördination in Engineering Instruction," by Prof. A. B. McDaniel, University of Illinois; "Study of Technical College Catalogs with Respect to Descriptions of Courses of Study and of Instruction," by Prof. H. S. Jacoby, Cornell University; Discussion. 3:45 P. M., *Papers on Fundamental Pedagogical Topics* (June BULLETIN): "Grading of Students by Universities *vs.* Grading of Technical Graduates by Employers," by Prof. C. F. Harding, Purdue University; "Better Text-books," by F. H. Sibley, University of Kansas; "A Report of Progress in Coöperative Education," by Prof. A. M. Wilson, University of Cincinnati; Discussion (including the article by Pres. W. M. Riggs, "Student Character Records," printed in the April BULLETIN). 4:30 P. M., Adjournment. 7:00 P. M., Annual dinner in the Graduate College dining room followed by the presidential address of Dean G. C. Anthony. Tickets for the dinner are $2 each and ladies are invited to attend.

FRIDAY, JUNE 26.

9:00 A. M., Council meeting. 9:30 A. M., Report of the Committee on Coöperation with Secondary Schools, Prof. H. E. Webb, Central Commercial and Manual Training High School, Newark, N. J.; Report of the Committee on Technical Nomenclature, Prof. J. T. Faig, University of Cincinnati. 10:30 A. M., *Papers on New Developments in College Courses* (June BULLETIN): "A Department of Engineering at the Johns Hopkins University," by Prof. J. B. Whitehead, Johns Hopkins University; "Proposed Courses in Structural Engineering for Civil Engineering Students," by Prof. W. M. Wilson, University of Illinois; "The New Mechanical Engineering Course at Columbia University," by Prof. Chas. E. Lucke, Columbia University; Discussion. 12:00 M., Adjournment followed by a meeting of the institutional delegates. 2:00 P. M., Organization meeting of the 1914–15 Council.

PRACTICAL MATHEMATICS.

BY W. S. FRANKLIN,

Professor of Physics, Lehigh University.

BARRY MACNUTT,

Associate Professor of Physics, Lehigh University, and

R. L. CHARLES,

Assistant Professor of Physics, Lehigh University.

In the teaching of mathematics every effort should be made to appeal to sense material and to the quantitative notions which permeate everyday life; and mathematical principles and relations should be visualized wherever it is possible. The development of workable ideas in a young man's mind is the most important object of science teaching; and ideas, like everything else in this world, have to be made out of *something*. Many teachers, however, seem to think that ideas can be built up in a young man's mind by a sort of hocus pocus out of nothing; but the only way to marshall the mind-stuff of a young man for the manufacture of ideas is to introduce the drag net of physical suggestion into every discussion. There is no other way to bring intuitive and sense material into the field of consciousness where it may be organized into a structure of ideas. An abstract and conventional treatment tends always to inhibit the influx of elemental mind-stuff into the field of consciousness, and such a treatment results at best in the building up (in the mind) of a theoretical structure which can have no mental traffic with anything outside of its own narrow boundaries. Such a state of mind, even when it is actually produced, is nothing but a kind of idiocy; and to call it a knowledge of mathematics is the silliest kind of scholasticism.

Many teachers of mathematics do, no doubt, appeal to sense material, and what we say as to the urgent importance of such

appeal is likely to be lost on them; for we have in mind a degree of appeal which is greater, perhaps than has ever been attempted, and *especially we urge the importance of incorporating this appeal in the printed text.* Men have but little native ability to understand impersonal and non-anthropomorphic writing, and nothing in elementary science training is more important than to develop this kind of ability. It depends not only upon *the possession of ideas* BUT IT DEMANDS THE ACQUIREMENT OF SOME OF THESE IDEAS BY READING.

According to our experience, engineering students willingly spend almost any amount of time and effort in algebraic transformations, in memorizing formulae and in solving numerical problems, but they cannot be made to read with care the briefest written statement or argument however simple it may be and however clearly written, and when they do read they cannot understand. This obstinate unwillingness to read and this fixed inability to understand are due very largely, we believe, to the influence of our mathematics teaching. What else could be expected when the great majority of engineering students never get a single idea from the book they study hardest—and hate the worst, their text book on calculus?

Professor Sylvester once said that during his undergraduate days his liking for calculus led his mates to look upon him with a kind of awe as a man who like Dante had seen Hell. But to study calculus without understanding is Hell; and the man to be likened to Dante is he who sees young men study, knowing that they do not understand! But let us turn from generalities to particulars.

Several years ago we gave the following "original" problem to a group of Freshmen engineering students as part of a final examination in elementary mechanics.

"A cart moves due northwards at a velocity of 11 feet per second. A man pushes downwards on the cart with a force of 200 pounds and a mule pulls northwards on the cart with a force of 50 pounds. At what rate does the man do work and at what rate does the mule do work?"

Forty-four per cent. of the class found that the man was developing four horse-power and the mule one horse-power! These students were not exactly stupid, either, they were merely Wild Indians of a very familiar and ubiquitous kind; their physical imagination had never been stretched beyond games and guns, or, maybe, never beyond articles of food and the members of their bodies! It is certain, at any rate, that to have specified the part of his body used by the man in the problem in pushing against the cart would have brought the problem vividly before every member of the class in its real aspects! Or, perhaps, many of the class were obsessed with the idea that any study in college must necessarily refer to elegant and unfamiliar things, like the boy who was asked to explain what is meant by the heat of combustion of coal. This boy answered at once, "It is the amount of heat obtained from a pound of coal," but he could not be led to say "When the coal is burned." And when the instructor finally put the direct question, "How do you get heat out of coal?" the boy answered, stammering, "Why, professor, I ——— I don't know."

This identical boy, who seemed not to know that coal must be burned to get heat out of it, came upon the following statement on the 23rd page of his Calculus in a two-page discussion of discontinuous functions and he came upon it several months before the question as to the heat of combustion was put to him:

"Another discontinuity is seen in the function

$$y = \frac{2^{1/x} + 2}{2^{1/x} + 1}$$

when $x = 0$. Here y approaches two limits, according as x approaches zero through positive or negative values.

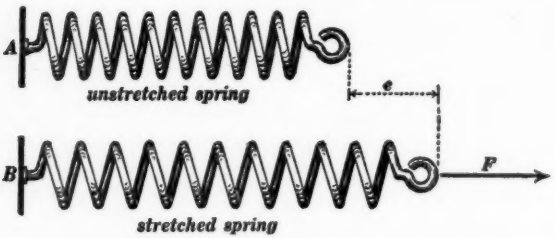
$$\text{Lim}_{x=+0} \frac{2^{1/x} + 2}{2^{1/x} + 1} = 1, \quad \text{Lim}_{x=-0} \frac{2^{1/x} + 2}{2^{1/x} + 1} = 2.$$

We see that when $x = 0$ the curve jumps from $y = 2$ to $y = 1$, that is from B to A (referring to a figure)."

In all probability, after "seeing" y jump in this elegant and

unfamiliar way, the boy really did not remember that coal must be burned to get heat out of it! Please recall Sylvester's allusion to Dante and consider what Dante saw (and understood, be it said to his everlasting fame), souls who had abandoned hope—and their tormentors!

Let us take another example. We recently gave to a group of Junior engineering students two problems involving the use of calculus, and there exists no problem involving the use of calculus which is simpler than either of the two we gave. The simpler of the two problems was as follows (the sketch here shown was given also to make the problem perfectly clear):



"The stretching force F, as shown in the sketch, is equal to ke where k is a constant. Find the expression for the amount of work done in stretching the spring from condition A to condition B."

There were 33 students in the class who had passed all of their freshman and sophomore mathematics, including analytical geometry, differential calculus, integral calculus, differential equations and analytical mechanics. Only 4 men formulated the problem correctly and derived the correct result; and of the 29 who failed utterly with a grade of zero 13 tried to argue the problem without using calculus! And yet, in the institution where this degree of mathematical power is realized, from 40 to 60 per cent. of the men fail to pass in each of the four successive terms of mathematics!

We realize with perfect clearness that these examples may be taken as a basis for unfavorable criticism of physics teach-

ing, *if we assume that power in mathematics has only to do with quick and complete response to a question like this. "Integrate kay Eee dee Eee between the limits Eee equals zero and Eee equals kay Eee!"* These examples show how nearly impossible it is to accomplish anything in elementary science teaching in the face of present-day mathematics instruction.

What is needed is to divorce the beginnings of elementary calculus from formal algebra, and to teach it as a branch of old-fashioned mental arithmetic. The widespread tendency towards the premature introduction of mathematical refinements and elaborations and the almost complete suppression of ideas by symbolism is perhaps the most serious fault in mathematics teaching. "Natural philosophy," says Bacon, "is not yet to be found unadulterated but is impure and corrupted by mathematics which ought rather to terminate natural philosophy than to generate or create it."

We have tried to keep away from vague generalities in the preparation of this brief, and yet in looking it over we realize that many of our statements grow out of very general considerations. It could not, perhaps, be otherwise, but our point of view seems to be different from that of most of our fellow-teachers, and therefore not to be easily understood by them. We assume, however, that most teachers recognize sorely the need of what Bacon listed as a deficiency in his day, namely, "The Traditive Lamp or the Proper Method of Delivering Down the Sciences to Posterity." We also assume that some teachers of elementary mathematical science are not wholly pleased with what they do. But especially, recognizing the very great preponderance of what may be variously called *ideas,* or *method,* or *theory,* in what is teachable in science, and knowing what a vast difference there is between such things as held in a system of philosophy and as realized in life, we recall this humiliating passage from Goethe:

> "Grau, theurer Freund, ist alle Theorie
> Und grün des Lebens goldener Baum."

The Maxwellian Method.

The method of the purist in mathematics is to develop an entirely consistent and rigorous system of symbolic logic, independently of every element of perception and judgment; and another method in mathematics is represented by Maxwell's great treatise on "Electricity and Magnetism," where highly elaborate mathematical forms spring, full fledged and rich, from physical ideas, bringing mathematics at once into touch with the experimental sciences and leaving the pure algebraist with his labored logic hopelessly behind.

The difference between these two methods is not the difference between rigor and mere plausibility, it is mainly the difference between a proud contempt for intuition on the one hand, and a straightforward use of intuition on the other hand. Consider, for example, the usual treatment of the discontinuity of functions in elementary treatises on calculus. What must any concretely-minded young man think of a writer who defines discontinuity as a break in a curve but who turns away from this definition as being intuitive, and proceeds to an algebraic discussion! Every concretely-minded young man would recognize the propriety of turning away from the broken curve in this matter; but to turn to algebra rather than to the vision of a poor trapped sparrow butting his head against a window pane, argues a kind of deep set and hopeless insanity!

In our opinion even elementary mathematics, including calculus, can be developed in full by the Maxwellian method on the basis of physical ideas, *and as logically as by the classical method.* But of course there is a difference in the logic. In one case the logic is machine made and its substance is algebraic transformation by rule; whereas, in the other case, the logic is involved in the perception of relationships between fairly complicated but entirely precise and unimpeachable ideas.

The association of a physical quantity with a definite physical thing or condition always involves a sharply defined idea

of invariance, as does also every mathematical definition in elementary physics and chemistry. Indeed the invariant relations which intervene between raw unformulated nature and what is ordinarily called mathematics are very great in number, and many of them rest upon very complicated experimental operations; and their clear recognition places an extremely severe demand upon the mind of any young man.* The necessity of rigorous thinking is much greater and more exacting in this border region than it is in the region of pure mathematics. Unfortunately, however, our conventional courses in mathematics seem always to produce a hopeless habit of vagueness in regard to mathematical ideas. For example, when asked to state Joule's Law, a student will say *aitch equals arr aye square tee!* It is difficult to get a student to say that *the amount of heat generated in a particular piece of wire during a given time is proportional to the square of the current in the wire and to the time that the current continues to flow.* It is difficult to get a student to appreciate the necessity of particularization in such a statement; by writing his statement down phonetically, he can indeed be shamed out of the statement of a physical law by the mere pronunciation of letters, but he is apt to think his statement completely and definitely physical

* Consider a movement of the x, y and z axes of refernce. This movement is a physical operation, and it is represented in algebraic terms as a linear transformation; that is to say, the coördinates of a point with respect to the new axes are linear functions of the coördinates of the same point with respect to the old axes. There are certain functions of x, y and z which are not changed by this linear transformation, and these functions are called invariants with respect to this particular transformation. That is to say, the movement of the axes of reference (a physical operation) leaves certain invariant relations outstanding. The systematic physical operations which are involved in any more or less elaborate experimental research or test always leave certain invariant relations outstanding, the clear and precise recognition of which is the essential part of the logic of experimental physical science—and a real and important branch of mathematics. Indeed the border region above mentioned is permeated by a most exacting kind of mathematics, which is akin to the group theory and to the theory of invariants.

when he says "Heat is proportional to current squared multiplied by time." It is extremely difficult to get a student to appreciate the invariant relation between the proportionality factor and the particular piece of wire, and it is hardest of all to bring a student to the point where his mind is directed to the physical operation which defines a quantity of heat, or a strength of current when such a quantity is mentioned.

Mathematics as it is given to students in our conventional courses is entirely lacking in that quality of precision and definiteness which goes with complete particularization. This statement will seem to be an exaggeration to many teachers, but let them consider that we mean by complete particularization that which would satisfy the most childish person in a talk about apples! The precision and definiteness, which goes with complete particularization is perhaps the only kind of precision and definiteness a beginner can appreciate, and we believe it is a great mistake to suppose that in the study of abstract mathematics a peculiar and inevitable kind of precision and rigor constrains the mind of a young man as a mould constrains molten iron! One might as well try to shape an iron casting in a mould of pure mist as to attempt to form a young man's mind by conventional mathematics.

The Study of Mathematical Science.

The greatest difficulty in the teaching of the mathematical sciences in the college and technical school comes from the fact that the average young man does not instinctively appreciate the necessity of rigorous thinking, and the greatest error on the part of a serious teacher is to assume that this difficulty can be met by mere exactions.*

* This is a natural difficulty, and it must be squarely met. A second difficulty is that young men in their study of the mathematical sciences are lacking in that eager interest which is called scientific curiosity. We are convinced, however, that this lack of interest is not inherent in the average young man; it grows out of the entire absence of suggestiveness in his mathematical studies and the inhibition of sense by the excessive formalities of ordinary mathematics instruction.

Nothing, perhaps, is farther from the usual ideals of mathematics than painting and sculpture; not indeed that the artist is free from exactions, for the saying that art is long and life is short certainly antedates our widespread academic pride in the difficulties of mathematics; but because the forms of expression in art are so different from the forms of expression in the mathematical sciences. And yet nothing has ever been said which can be more justly applied in criticism of our conventional courses in mathematics than the following criticism of conventionalized art. This criticism was made by one who, as Mazzini said, could hold a fact more fixedly in mind than any other man living in his time and set it forth more clearly. The criticism is expressed in terms of a contrast between The Two Paths* of art and it is illustrated by examples chosen from early barbarisms.

"The substitution of conventionalism for sympathy with observed life is the first characteristic of the hopeless work of all ages, and it is eminently manifested in the accompanying picture of an angel from a psalter of the Eighth Century which is to be found in the library of St. John's College,

An angel of the eighth century. The beginnings of art in England.

Cambridge. This angel is a barbarism from which nothing could emerge, for which no future was possible but extinction. It represents an utterly dead school of art which closed its eyes to natural facts (for however ignorant a person may be he need only look at a human being to see that it has a mouth as well as eyes) and made the attempt to adorn or idealize

* The title of Ruskin's lecture from which the criticism is taken.

natural facts according to its own notions (for it put red spots in the middle of the shands and sharpened the thumbs thinking to improve them). Here you have an example of the worst that is possible in idealism. Whenever people don't look at nature they always think they can improve her."

"From this dead barbarism let us turn to a living barbarism, to work done by hands as rude and by minds as uninformed, let us turn to a picture of the Serpent Beguiling Eve, from the Church of St. Ambrogio of Milan. Its date is not known but it is barbarous enough for any date: but rude and ludicrous as the sketch is, it does certainly have the elements of life in it. The workman's whole aim was straight at the facts, and not merely at the facts but at the very heart of the facts, for he did indeed show Eve's state of mind, that she is pleased at being flattered and yet in an uncomfortable mood of hesitation; some look of listening, of complacency and embarrassment he did verily get into the picture; note the eyes

The Serpent Beguiling Eve. The beginnings of art in Italy.

slightly askance, the lips compressed and the right hand nervously grasping the left arm. Nothing was impossible to the people who began their art thus. The world was open to them and all that is in it; whereas nothing was possible to the man who did the symmetrical angel, the world was keyless to him. He built a cell for himself in which he was barred up forever."

Our conventionalized courses in mathematics do not, however, take strong enough hold on young men to shut them up,

as in a cell, forever! No, they certainly do not! But these courses do tend to separate ordinary mathematical ideas from sense material: whereas the very essence of physics and chemistry is to bring mathematical ideas to bear upon sense material!

Our demand is that calculus, for example, be made intelligible to students; and in making this demand we do not make any objection whatever to the placing of exactions upon young men. In fact we know that very great exactions are necessary. But to place before young men that which is exacting and unintelligible is a fatal error, an error which seems to be widely prevalent among mathematics teachers.

The Use of Differentials in Calculus.

We find it difficult to understand the rabid objection of some of our mathematical friends to the old fashioned way of talking about differentials, except on the assumption that the idea of a limit must be much more difficult to the student of mathematics, in a narrow sense, than to the student of physics. Nothing indeed so clearly indicates the extreme difficulty which one has had in the acquirement of a precise idea as the notion that everyone else must be in a state of confusion in regard thereto, and our mathematical friends seem to imagine that they are combating a widespread confusion of mind in this matter, whereas the question at issue is merely as to the relative merits of two modes of expression.

Consider the simple function $y = ax^2$ from which we find

$$\frac{\Delta y}{\Delta x} = 2ax + a \cdot \Delta x,$$

and from this expression it is evident that $\Delta y/\Delta x$ approaches $2ax$ as its limiting value as Δx approaches zero. That is, we have:

$$\frac{dx}{dy} = 2ax.$$

The use of the complicated group of letters dy/dx for the

derivative reminds one of the ratio $\Delta y/\Delta x$, the use of d instead of Δ is intended to bring to mind the limiting value of $\Delta y/\Delta x$, *and the great majority of writers on applied mathematics are in the habit of speaking of the differential, dx, as a vanishing increment of x in order that the above argument may thereby be called to mind.* The sole value of this mode of expression is its suggestiveness.

The Syllabus Definition of a Differential.

After a body falls for one second under the action of gravity it has a velocity of 32 feet per second, *which means that the body would travel 32 feet during the next second if its velocity were to remain unchanged.* Similarly, in the simple differential expression $dy = 2ax \cdot dx$, the variable y changes 20 times as fast as x when x has reached the value of 10, *which means that dy (the actual finite change of y) would be 20 times dx (the actual finite change of x) if y were to continue to change 20 times as fast as x.* This statement involves a precise definition of dy and dx, there is no doubt about that; but what use can such a definition be for the purpose of simple, concrete and suggestive discussion with its extremely awkward "would be's" and "if's"? And yet this is the meaning which the purists wish to have always brought to mind when the differentials dy and dx are mentioned! In order to bring out the real question at issue let us compare the following three statements, *A*, *B* and *C*.

A. Example of an Argument for Setting up a Differential Equation.—Let it be required to set up an expression for the derivative dK/dr, where K is the moment of inertia of a circular disk of radius r referred to its axis of figure. Let m be the mass per unit area of the disk. Then $[\pi(r+\Delta r)^2 - \pi r^2]m$ or $2\pi rm \cdot \Delta r + \pi m(\Delta r)^2$ is the added mass due to the increment Δr. The distance of the added mass from the axis is greater than r and less than $r + \Delta r$; therefore* the incre-

* The reason for multiplying the added mass by the square of its distance from the axis is here omitted.

ment of K lies between

$$r^2[2\pi rm\cdot\Delta r+\pi m(\Delta r)^2] \text{ and } (r+\Delta r)^2[2\pi mr\cdot\Delta r+\pi m(\Delta r)^2].$$

Therefore, expanding and collecting terms, we get:

$$\frac{\Delta K}{\Delta r} \text{ lies between } \{2\pi r^3m+\pi r^2m\cdot\Delta r\}$$

and

$$\{2\pi r^3m+5\pi r^2m\cdot\Delta r+4\pi rm(\Delta r)^2+\pi m(\Delta r)^3\},$$

but both of these expressions approach $2\pi r^3m$ as a limit as Δr approaches zero, and therefore the limiting value of $\Delta K/\Delta r$ is $2\pi r^3m$. That is:

$$\frac{dK}{dr}=2\pi mr^3.$$

B. An Epitome of the Argument A.—The added mass is $2\pi rm\cdot dr$ (because one recognizes $2\pi r\cdot dr$ as the limiting form for expressing the area of a narrow circular annulus).

We multiply the added mass by r^2 to get dK (because one recognizes r^2 as the limiting value of anything which lies between r^2 and $(r+\Delta r)^2$).

Therefore $dK=2\pi r^3m\cdot dr$.

Note.—Every one no doubt appreciates the fallacies in this kind of abbreviated argument, but the mathematicians alone seem not to appreciate its value as a suggestive outline. The matter in the parentheses is indeed usually omitted from abbreviated arguments of this kind, but even when such material is included the argument is incomplete because it does not include explicitly everything that is given under *A*. The great majority of writers on applied mathematics do not use the Δ notation in the early part of an argument and change to the d notation when the limit is determined, but for brevity they use the d notation first and last.

C. Attempt to Give an Epitome of the Argument A Using the Syllabus Definition of the Differential.—The differential dK is the increase which would be produced in K due to a finite increase of r (namely dr), if the rate of increase of K

with respect to r were to remain constantly equal to the value which the derivative dK/dr has for the initial value of r. That is $dK = (dK/dr) \cdot dr$!

And here we come to a dead stop; the syllabus definition has its tail in its mouth! It is entirely useless in the setting up of an epitome of the argument A, and it is utterly devoid of suggestiveness; its only use, indeed, is that it enables one to write down such an expression as $dy = 2ax \cdot dx$ in vain pride of precision and rigor.

It is time, however, that our mathematics teachers should realize that mathematics is not merely writing down letters, however great their readiness may be to give a simple explanation of what the letters are supposed to stand for. Ask a young man what he gets when he multiplies 2 dollars per day by 500 days, and he will say, correctly, 1,000 dollars. But if you ask him how to perform such a profitable operation, he will wonder what you can possibly mean by profit in speaking of mathematics! To multiply 2 dollars per day by 500 days means to work hard for 500 days! That is what this particular multiplication means, and nearly every mathematical process rightly understood refers to physical reality in a manner scarcely less definite and exacting. Writing down symbols indeed! The wonder is that any amount of conceited and reentrant logic could make some of our mathematics teachers unashamed in view of what they accomplish in the class room, which is vanishingly small.

THE PROPER USE OF THE DIFFERENTIAL IN CALCULUS.

BY EDWARD V. HUNTINGTON,

Assistant Professor of Mathematics in Harvard University.

The Right Way to Introduce the Differential Notation.*

Every time an observant student examines the graph of a function $y=f(x)$ in an interval from $x=x_1$ to $x=x_2$ (see

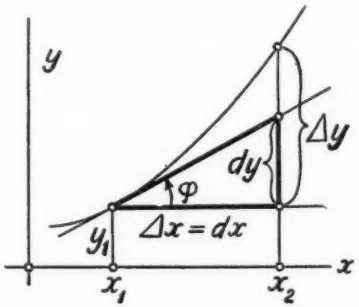


figure), there are three concrete geometrical magnitudes which immediately compel his attention:

(1) The increase produced in the function by the increase given to x; this increase we denote by Δy (called the increment of y);

(2) The increase that would be produced if the curve coincided with its tangent at the point x_1; this increase we denote by dy (called the differential of y);

(3) The slope or gradient of the tangent line; this slope is called the derivative, and may be denoted, for the moment, by $\tan\phi$.

* The following brief account of the differential notation is essentially that given in the Syllabus of Mathematics, published by this Society. For a fuller account, see any good text-book on calculus.

Of these three quantities, we see at once that $\tan \phi$ depends only on the value of x; Δy and dy, on the other hand, depend also on the increment given to x, which (when x is the independent variable) we may agree to denote at pleasure by either Δx or dx.

All these quantities are definite, concrete geometrical magnitudes, whose existence and importance cannot fail to be patent to any student who uses his eyes. A relation between them is obviously

$$\tan \phi = \frac{dy}{dx},$$

since in any right triangle, the tangent of an angle is "the side opposite divided by the side adjacent." Moreover, if we choose to make Δx vary, so as to approach zero as a limit, then $\lim [\Delta y] = 0$, $\lim [dy] = 0$, and $\lim [\Delta y / \Delta x] = \tan \phi$, this last relation providing us with the well-known method of computing analytically the value of the derivative.

All this is so well known that it seems almost an impertinence to take the time of this Society to present it. And yet, in view of recent discussion of the matter,* I believe that there are two considerations to which it would be well to call attention.

The first is this: *In spite of the fact that all competent mathematicians have long been perfectly clear on this subject, there are still many recent textbooks (chiefly those intended for students of engineering or physics) in which the differential notation is treated in a manner so vague and confusing as to deprive it of all practical value.*

To prove this statement, I beg to cite the following passages from widely used textbooks, all of which have been published since the beginning of the twentieth century.

* I refer especially to an article by Professors Franklin, MacNutt, and Charles in the present issue of the BULLETIN, which contains a vigorous attack on the Syllabus definition of the differential.

EXAMPLES OF BAD METHODS OF TREATING THE DIFFERENTIAL.

One very common method is illustrated by the following quotations:

(1) J. W. Mercer, "Calculus for Beginners," 1910, p. 50 (in bold face type): "*ds* and *dt* have no separate meanings; *dt* does not stand for a small increment in *t*, nor *ds* for a small increment in *s*. $\frac{ds}{dt}$ must be treated as a whole. It does not mean the result of dividing *ds* by *dt*."

(2) D. A. Murray, "Infinitesimal Calculus," 1903, pp. 43 and 49: "The symbol $\frac{dy}{dx}$ does not denote a fraction; it does not mean the ratio of a quantity dy to a quantity dx. It must be clearly understood that the cancellation of the dx's in the equation $dy = \frac{dy}{dx}dx$ is impossible."

(3) John Perry, "Calculus for Engineers," 4th edition, p. 15: "The symbol for this rate is $\frac{dy}{dx}$. Observe that it is one symbol; it does not mean $\frac{d \times y}{d \times x}$."

(4) Franklin and MacNutt, "Elements of Mechanics," 1908, p. 44: "The symbol dS/dt is one single algebraic symbol, and it is not to be treated otherwise."

These writers evidently do not regard dx and dy as quantities at all. For them, the symbol $\frac{dx}{dy}$ means $\frac{d}{dx}(y)$, where $\frac{d}{dx}$ is a symbol of operation, and y is the quantity on which the operation is performed. Logically, of course this is a perfectly tenable position. But from the point of view of practical convenience it is hardly defensible. For if all one wants is a symbol of operation, D_x is simpler than $\frac{d}{dx}$ and the chief advantage of the notation $\frac{dy}{dx}$ is entirely lost if we are not allowed to separate the dy and dx. I can imagine few things more tantalizing to the student than to be obliged to remember constantly that a symbol which has been specially

constructed so as to look like a fraction must never be used as if it were one!

A second and more common view of the differential notation is the following:

(5) Geo. A. Osborne, "Differential and Integral Calculus," revised edition, 1906, pp. 68 and 73: "The differential of any variable quantity is an infinitely small increment in that quantity. Thus dx is an infinitely small Δx, and dy is an infinitely small Δy. An infinitely small increment, or infinitesimal, may be defined as a variable whose limit is zero."

But this is surely no adequate definition of a differential. For the increment Δy is also "a variable whose limit is zero"; hence the definition gives us no criterion by which to distinguish between Δy and dy; and if dy and Δy are the same, there is no occasion for introducing the symbol dy at all. That there is much confusion in the books on this point is attested by

(6) J. W. Mellor, "Higher Mathematics for Students of Chemistry and Physics," second edition, 1905, p. 18: "As a matter of fact, the symbols dx, dt, etc. are constantly used in place of Δx, Δt, etc."

A third point of view is illustrated by the following citations:

(7) John Graham, "Elementary Treatise on the Calculus," 4th edition, 1914, p. 25: "When δt [or Δt] is *indefinitely small, that is, smaller than .000 000 000 1*, it is denoted by dt, and the corresponding increment of space by ds."

According to this author, a variable increment is to be denoted by Δy or by dy according as it is greater or less than .000 000 000 1! One is left to wonder whether this means one billionth of a millimeter or of a light-year! Scarcely less naïve are the following:

(8) J. W. Mellor, *loc. cit.*, p. 32: "Our reason is satisfied to reject the differentials when they become so small as to be *no longer perceptible to our senses.*"

(9) W. Watson, "Text-Book of Physics," 1907, p. 27: To measure instantaneous speed, we divide the space by the time, taking the interval of time "so small that the speed does not appreciably alter" during that interval.

10) Henry S. Carhart, "Physics for University Students," 1906, p. 11: "Let M and M' be the positions of the particle at epochs t and t'. Then $v = MM'/(t' - t)$ is the mean velocity during the time $t' - t$. [To obtain the instantaneous velocity at the time t] imagine now MM' to be reduced to infinitesimal dimensions, and let its value then be represented by ds. Also let the time of traversing this minute distance be dt. Then precisely as before, $v = ds/dt$."

For these writers, a differential is a quantity which is apparently finite, but so small that whenever it occurs by itself (not in a ratio with another), it may be neglected without "perceptibly" or "appreciably" damaging the result. Such a definition is clearly unsatisfactory; for if this were really what we meant by dx and dy, the results obtained by the methods of the calculus would be only approximately true!

The approximate character of the results of the calculus is indeed sometimes admitted; for example:

(11) J. W. Mellor, *loc. cit.*, p. 14: "The symbol '=,' when used in connection with differential coefficients, does not mean 'equal to,' but rather 'can be made as nearly equal to as we please.'"

Most writers, however, insist that whatever may be said of the method, the results at least are correct. This leads to what I shall call the fourth method of defining a differential.

(12) John Goodman, "Mechanics Applied to Engineering," 1903, p. 556: "It will be seen that if Δl be taken large, error will be introduced, and that the error becomes smaller as Δl becomes smaller, and that it *disappears when* Δl *becomes infinitely small.*" When this happy state is reached, "we substitute dl for Δl."

In other words, dl is that value of Δl for which the error produced is zero. But a moment's thought will show that the only value of Δl for which this is true is $\Delta l = 0$; for if Δl has any value other than zero, the actual size of the error produced can be readily computed. Hence this definition of dl is equivalent to saying that $dl = 0$! Here at least we seem to be on clear ground! The differential of a quantity is the simplest thing in the world, namely zero!

But hold. Are we quite sure that we understand what

these authors mean when they use the symbol 0? Let us listen again to Mr. Mellor:

(13) J. W. Mellor, *loc. cit.*, pp. 10 and 12: "I suppose that the beginner has only built up a vague idea of the magnitude of differentials or infinitesimals. They seem at once to exist and not to exist. I will now try to make the concept more clearly defined. In mathematics, two meanings are given to the word zero—*absolute zero* and *relative zero*. Relative zero is defined as an infinitely small or vanishing small number. For example, we might consider a point as an infinitely small circle. Tersely, relative zero implies that however small a thing may be, its property of growing small without limit is alone retained in the mind."

Here then is a fifth definition of a differential. It is not an absolutely zero but only a "relative zero"! And to explain what is meant by a relative zero we are asked to consider a point as a small circle whose only property is the property of growing smaller! It is difficult to take such statements seriously; and yet they are by no means uncommon. Thus:

(14) A. H. Angus, "Differential and Integral Calculus," 1906, p. 15: "When a quantity becomes indefinitely small, far too small for human, mental conception, we call it infinitely small, and we write it mathematically '0,' called nought, or zero. Thus, as well as denoting what we familiarly call nothing, the symbol 0 is also used to denote a quantity so small that we are unable to distinguish the difference between the quantity and nothing."

In other words, mathematical zero is directly dependent on the power of our microscopes!

Such are the confusions into which one is led when one attempts to define a differential as an infinitely small increment. One can never tell in advance what a given writer is going to mean by infinitely small. Some writers, as we have seen, mean merely a variable increment approaching zero as its limit, and therefore use dy and Δy quite indiscriminately (as, for example, John Perry, *loc. cit.*, p. 142); others mean a constant magnitude negligibly small, and therefore abandon all claim to accuracy in their results; while others mean either a flat zero, or else one of those "relative zeroes," which at the same time "exist and do not exist," one of those "ghosts of

departed quantities" which Bishop Berkeley so justly satirized in the early years of the science.

Finally, there is a sixth way of treating differentials which is purely abstract and conventional, utterly devoid of any "appeal to sense material, or to the quantitative notions which permeate everyday life." For example:

(15) Franklin, MacNutt, and Charles, "Calculus," 1913, p. 19: "After defining the derivative quite correctly as the limit of the quotient $\Delta y/\Delta x$, they introduce the differential, in connection with the equation $\frac{dy}{dx}=2ax$, as follows: "Heretofore we have looked upon $\frac{dy}{dx}$ as a single symbol. *Convenience of notation sometimes makes it desirable to write the equation thus:* $dy=2ax\,dx$. dy is called the differential of y and dx is called the differential of x."

This is obviously the merest juggling. Since neither dy nor dx has been so much as mentioned up to this time as a separate entity, how can the student attach any real meaning to the so-called equation $dy=2ax\,dx$? The guidance of analogy, which doubtless suggested the breaking up of the symbol dy/dx into parts, is just as dangerous here as in the familiar schoolboy method of treating the symbol $\sin^{-1}x$. What the method might lead to, if consistently applied, may be seen in the following parallel:

The angle whose sine is y we denote by $\sin^{-1}y$, the symbol $\sin^{-1}$ being one symbol, denoting an operation performed upon y. For example, suppose

$$\sin^{-1}y=\pi.$$

Now $\sin^{-1}$ looks as if it meant $1/\sin$. "For convenience of notation," then let us write the equation thus:

$$\frac{y}{\sin}=\pi, \quad \text{or} \quad \sin=\frac{y}{\pi};$$

and in this equation, let us call sin the "crust of the π."

The limit of the ratio $\Delta y/\Delta x$ we denote by $\frac{dy}{dx}$, the symbol $\frac{d}{dx}$ being one symbol, denoting an operation performed upon y. For example, suppose

$$\frac{dy}{dx}=2ax.$$

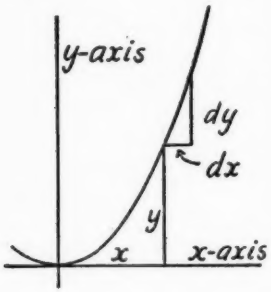
Now $\frac{dy}{dx}$ looks as if it meant $dy \div dx$. "For convenience of notation," then, let us write the equation thus:

$$dy=2ax\,dx;$$

and in this equation, let us call dy the "differential of y."

The parallel is an absolutely true one; each column purports to define a new mathematical symbol, and the method in one column is no better and no worse than the method in the other column.

The authors of course add the usual explanation that "*dy* and *dx* may be thought of as indefinitely small increments of *y* and *x* respectively"; and on p. 24 they give the adjoining figure, as an illustration of the equation $dy = 2ax\,dx$, which they maintain is "rigorously true." I will leave the reader to determine for himself which of the possible meanings of "infinitely small" these authors probably had in mind when they drew this figure. The contrast between their figure and the standard diagram at the beginning of this article will well repay careful study.



The above quotations, selected almost at random from textbooks in current use today, are sufficient, I believe, to establish my first thesis.

The Usefulness of the Differential Notation in Applications.

I now turn to my second thesis, namely, that *the orthodox mathematical definition of a differential, as briefly sketched at the beginning of this article, provides precisely the direct and suggestive notation which the workers in applied mathematics require, since it enables one to proceed rapidly and directly to the desired "answer" without the necessity of stopping to put in every step of the reasoning unless one wishes to do so.** In other words, the differential notation stands ready to supply all the "rigor" that may be desired

* This statement is stoutly denied by Professor Franklin, MacNutt, and Charles, but the alleged illustration which they give under the heading "C" is a mere travesty on the Syllabus method which no mathematician would thing of using.

whenever it is wanted; but it does not obtrude its rigor on the attention of anyone who may wish to travel light and cut the corners.

The usefulness of the differential in applications depends on the following theorem:† *In all the ordinary problems about the "limit of a ratio" and the "limit of a sum," we may replace* Δy *by* dy*, without altering the final result.* Or, briefly: *In all ordinary cases,* dy *is a good approximation to* Δy.

This theorem of course requires amplification and proof (the proof will be rigorously studied or taken largely on faith, according to the temperament of the student); but when once accepted, it provides one of the most elegant and powerful tools which pure mathematics has ever contributed to science.

For illustration, let us take the following example of the process of setting up a differential equation.‡

A. Complete Form of the Argument, by the Method of Limits.—Let it be required to set up an expression for the derivative dK/dr, where K is the moment of inertia of a circular disk of radius r referred to its axis of figure. Let m be the mass per unit area. Then $\Delta m = [\pi(r+\Delta r)^2 - \pi r^2]m = 2\pi rm\Delta r + \pi m(\Delta r)^2$ is the added mass due to the increment Δr. The distance of the added mass from the axis is greater than r and less than $r+\Delta r$; therefore the increment in K lies between $r^2\Delta m$ and $(r+\Delta r)^2\Delta m$. Expanding and collecting terms, we find that $\Delta K/\Delta r$ lies between $[2\pi r^3 m + \pi r^2 m\Delta r]$ and $[2\pi r^3 m + 5\pi r^2 m\Delta r + 4\pi rm(\Delta r)^2 + \pi m(\Delta r)^3]$. But both of these expressions approach $2\pi r^3 m$ as a limit as Δr approaches zero, and therefore $dK/dr = 2\pi r^3 m$.

B. Abbreviated Form of the Argument, by the Use of Differentials.—The added differential of mass, due to the increment dr, is $dm = 2\pi rmdr$ [because one recognizes $2\pi rdr$ as a "good approximation" to the area of a narrow circular annulus whose length is $2\pi r$ and width dr].

† For a more exact statement of this and related theorems on infinitesimals, see the "Syllabus of Mathematics."

‡ This is the same example as that used by Professors Franklin, MacNutt, and Charles.

The distance of the added mass from the axis is r [because one recognizes r as a good approximation to anything that lies between r and $r+dr$.] Therefore $dK=2\pi r^3 m dr$.

There are no "fallacies" in this kind of abbreviated statement. It differs from the complete statement A only in this respect: In B we use the results of a theorem which is supposed to have been proved once for all, while in A we repeat, for the particular case before us, the details of the proof of that theorem.

Moreover, the attitude of the student's mind toward this process is a perfectly normal and intelligent one. There is nothing mysterious or vague in the statement that "the area $2\pi r dr$ is approximately equal to the area of a certain circular annulus," since $2\pi r dr$ is a perfectly definite area, and the difference between it and the annulus in question, for any given values of r and dr, can be written out at length.

Compare this with such a statement as the following, which the authors above cited are fond of using: "$2\pi r dr$ is the *limiting form* for expressing the area of a narrow circular annulus." What is a "limiting form"? Is it a quantity, or not a quantity? If it is a quantity, how big is it? If it is not a quantity, what right has it to stand as one member of a mathematical equation?

It is this question of the attitude of the student's mind which must be the central question in any discussion of methods of teaching. If the orthodox mathematical method of defining differentials, as sketched above, leads the student to form a definite, concrete picture of what he is doing when he manipulates these symbols—and I am convinced that it does do so—then that is the method which we all ought to teach. If on the other hand any method is presented which compels the student to handle his mathematical symbols in a purely mechanical fashion, not translatable into visual or quantitative terms—and I believe that each of the six types of "bad methods of defining the differential" cited above falls under this category—then such a method ought to be abandoned as a menace to clear thinking and effective progress.

THE CALCULUS WITHOUT SYMBOLS.

BY E. R. HEDRICK,

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It is reasonably easy to state most of the results of the calculus in a form which requires no previous mathematical training and which employs no symbols of any sort, except only English words.

That this is true perhaps passes the belief of those to whom mathematics as a whole and the calculus in particular is only a mass of meaningless letters and formulas. In this paper it is my purpose to demonstrate this possibility on a few examples which are by no means altogether elementary. My hope is that this will tend to awaken a keener interest on the part of teachers in emphasizing the living truths of the calculus at the expense of the pure formalism which too often conceals these truths; and also to inspire present and past students of this subject with a livelier appreciation of its actual content.

To members of the S. P. E. E. what I have to say will not seem strange, except in that it comes from the lips of a professed mathematician. For you are for the most part men accustomed to deal with actual quantities,—with real *things*. You commonly think in the terms I shall use here. It is rather for the many who are not present, whom your society will help me reach, that I speak as it were not *to you* but only under your auspices.

Rates of Change.

Quantities in nature change continually. Those that do not are largely figments of men's imaginations. The changes in quantities are *fast*, or *slow*, or just *middling*. That is, whenever changes occur, we may speak of the *rapidity* of those changes. I say that the total of the rapidities of the changes

that are going on all about us constitutes what is called LIFE if I may use that word not in its biological sense, but as opposed to stagnation.

Thus we say that sugar dissolves rapidly in water. The rapidity of solution decreases as more sugar is dissolved, and indeed the sugar dissolves more and more slowly until no more will dissolve. We say that the rate at which the sugar dissolves steadily decreases and approaches zero.

Or we speak of the growth of a child, or of a tree, or of a nation. Rapidity of growth is interesting, whether it be of a child, of a nation, or of an electric current.

Any intelligent study of such rates of change is and of a right ought to be a chapter of the calculus, whether symbols are used in that study or not. The hydraulic engineer using a mass curve, which actually represents the total rainfall from a fixed starting date, is just as truly employing the calculus as is the statistician when he notices that the slope of a curve which represents the population of a state gives the rate of growth of that population. Neither uses any equations for his curves.

Anyone who speaks of rapidity of change of anything, and makes intelligent comments about it, is discussing the calculus. The test is not that he should use symbols; it is that the comments be intelligent. On this basis, if you accept it, some topics not commonly included in calculus would be included, and possibly some topics ordinarily included would be discarded.

I may observe, for example, without use of symbols, that if the rapidity of change sinks to zero and remains zero, the quantity concerned does not change at all. Thus, in the saturated sugar solution, the amount of sugar in solution remains fixed after saturation occurs. This is the so-called *fundamental theorem* of the integral calculus. I shall use it again later.

Conversely, if a quantity does not change, the rapidity with which it changes is zero. This is the first formula of differentiation.

If several changing quantities of the same kind are put together, the rapidity of change of the whole is the sum of the separate rates of change, if all other external conditions remain fixed. And so on.

Maxima and Minima.

If a quantity is increasing for a time and then begins to decrease its rate of change is said to be positive while it is increasing and negative while it is decreasing. Barring any violent alteration of external conditions, the rate of change must have been zero at some instant before the quantity decreased. Thus the maximum value of a quantity occurs at a time when its rate of change is zero; just previous to this instant the rate of change must have been positive, and just afterward negative.

For example, if the temperature rises and falls during the day, it is clear that the rate of change of temperature is zero at the hottest instant, and also at the coolest instant; the two instants differ in that just before the hottest instant the temperature was rising, while just before the coolest instant the temperature was falling.

This is, of course, a pretty fair discussion, in brief, of the conditions for maxima and minima. As noted, any sudden alteration or stoppage of external conditions is barred.

I do not see what is to prevent my discussing any topic of the calculus in just such a manner. Where am I forced to stop? But one objects that I have not described accurately what is meant by a rate of change. Nothing is easier. I have not done so largely because this one topic is now handled fairly well in several, but by no means all, text-books, in plain English. The amount of a change in a short period of time is actually measurable; the average rate of change during that period is the ratio of the amount of the change to the length in seconds of that period of time. The limit approached by this ratio as the time diminishes toward zero as a limit is what is meant by the (instantaneous) rate of change.

To my mind this notion of rate of change (at an instant) is quite common even with untrained persons; certainly it is part of the everyday experience and usage of most cultured persons of intelligence.

But another says that I have omitted to mention many a formula and many a functional sign. As for the signs, I have for to-day explicitly disavowed them. As for the many, many facts that may be intelligently stated about rates of change, I shall certainly not attempt to rehearse them all now, since there are to be other exercises this week. The question is, *which one* would you have me do? Which one can I not state in plain English? This is a challenge. And if there be an intelligible fact about rates of change which cannot be expressed in the English language, I will have none of it in a course on the calculus.

What is Integration?

I should before closing at least refer to integration. The most vital point is that the knowledge of the rate of change of a quantity together with the knowledge of its original value, suffices to completely determine the value of that quantity at any time.

How do I know that this is accurately true? Why, because two different quantities that have the same rate of change surely maintain a constant difference, since the rate of change of their difference is zero. This proves, then, the most crucial fact about integration. In the proof I have used the "fundamental theorem" referred to above.

All that remains to be done is to discover by some device one single expression which has the given rate of change, since I have shown that the desired result must differ from it at most by a constant. This trick of discovery of a quantity that has a given rate does necessitate a ready knowledge of the rates of change of a grand variety of formal expressions, if one is to make quick and accurate guesses of quantities that have given rates of change.

Integral tables can be purchased which help to supply this need. It is certainly true that a knowledge of algebraic symbols is quite necessary to intelligently read these tables. But this does not violate my principal contention, for it is equally true that a knowledge of algebra is quite necessary to read intelligently almost any modern set of tables; emphatically it is to read any modern engineers' handbook! The occurrence of the algebraic formulas is not especially due to the calculus and its ideas. Their occurrence is rather the *cause* for the occurrence of any formulas in the calculus. But for the fact that scientists do use algebraic formulas in their work, the *principles* of the calculus would all remain intact and without any formulas whatever.

Thus, when a scientist does happen to need no formulas, as in the case of the hydraulic engineer in his consideration of rainfall estimates, the calculus does not impose any formulas upon him. It is a fact, for example, that the property that the derivative of an integral is equal to the integrand is used by these engineers without the intervention of any formulas, in that they notice that the slope of the mass curve gives the actual rainfall.

I have spoken largely of time-rates. But rates of change with respect to other basal quantities than time are common enough, even in everyday experience of the non-mathematician. Thus the length of a metal bar changes with its temperature. The rate of change of length with respect to temperature change is just as instinctive as is a time-rate.

We might indeed speak of the rate of change of the length with respect to time, that is *per second,* and quite distinctly of the rate of change of length with respect to temperature, that is *per degree Fahrenheit.* If we know also the rate of rise of temperature per second, it is easy to see—and quite easy to prove—that the rate of change of length per second is equal to the product of the rate of change of length per degree and the rate of change of temperature per second.

The general rule follows readily; it is the so-called rule for differentiation of a function of a function, and is quite formidable to many when stated in symbols, with no concrete explanation of its significance.

Of course I have told you nothing new. I did not wish to do so. My desire was only to maintain that the fundamental ideas of the calculus can be stated without recourse to any symbolism, and are in themselves quite free from symbols of any sort. I have challenged the production of a single fundamental fact which contradicts this thesis.

Knowledge of algebraic formulation is desirable for scientific work in engineering. Obviously no man can claim to have any adequate idea of engineering if he cannot understand formulas and algebraic symbols. Laws of nature seem awkward without such formulation, and any handling of these laws is at best clumsy without algebra. I have admitted freely that this means that these same facts and laws of nature must be dealt with in the calculus by means of symbols. Just as no engineer is worthy of the name who knows no algebra, so no calculus wholly without symbols would be adequate for the demands of science. Courses in calculus should contain a very great amount of formal expression and algebraic symbolism. My thesis is not that the calculus cannot be *applied* to formalized expressions, for such a claim would be ludicrous. My claim is that the fundamental ideas of the calculus are not in themselves formalized expressions, and that the handling of algebraic expressions in the calculus is to be regarded as an *application* of the principles of the calculus rather than as its true subject-matter.

The principles of the calculus without symbols ought to be made vividly clear to every student of engineering. There are evidences that the same knowledge would not be amiss in purely academic quarters.

EDUCATION IN SCIENTIFIC MANAGEMENT.

BY HUGO DIEMER,

Professor of Industrial Engineering, Pennsylvania State College.

Education in the principles of scientific management, in applied methods of scientific management, in allied or related arts and sciences, or in all of the foregoing, is being offered at the present time by corporation schools, correspondence schools, secondary schools, undergraduate schools of collegiate grade, and graduate schools. Moreover in many schools where there has been no direct formal teaching of the principles or applied methods of scientific management, these principles and methods have been utilized in the work of the class-room, the laboratory, or the shop, by men in charge.

There is a constantly increasing number of individuals who have pursued a course of some kind or another either in scientific management or in matters which in their opinion are equivalent, sufficient to justify them in their own minds in either assuming the title of efficiency engineer, industrial engineer or efficiency expert, or at least in assuming the ability to do the work ordinarily undertaken by those who call themselves by these titles. It would be unfair to accuse these individuals of misrepresentation because we have not as yet any authorized standards by which to measure the preparation, experience and ability of those who are licensed to use these titles.

There is no clearly defined meaning attached to the words "course of study," so that when we speak of a course in scientific management, unless we explain ourselves more fully, our hearers do not know whether we refer to a course of reading, a course of an hour or two a week for half a school year, or an extended series of studies representing four years more of specialized collegiate work with a preparation of twelve years preliminary schooling.

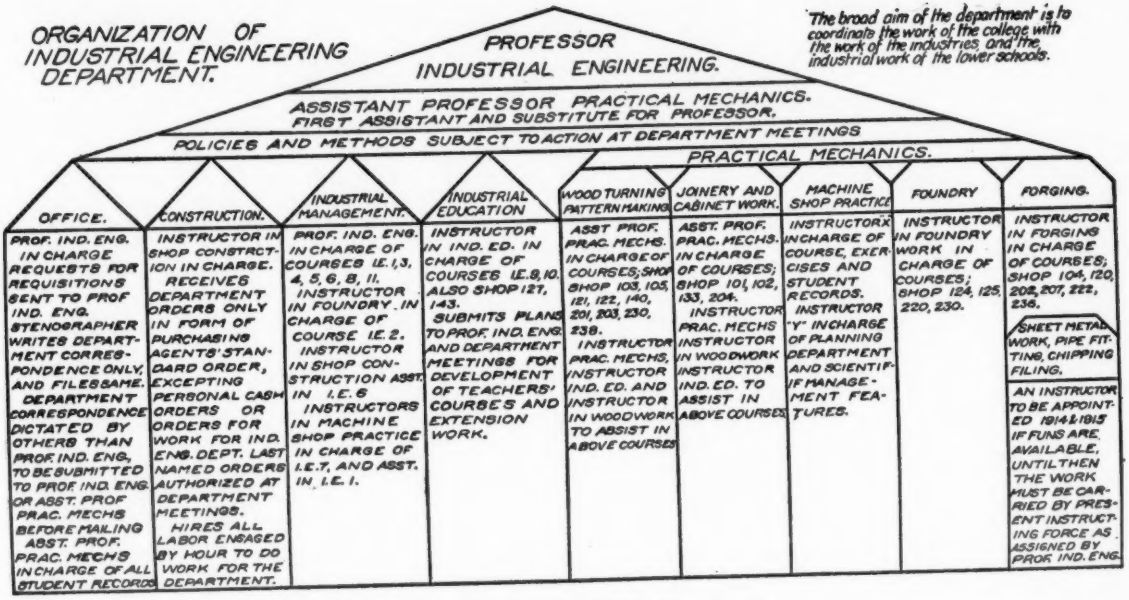
ORGANIZATION OF INDUSTRIAL ENGINEERING DEPARTMENT.
"The broad aim of the department is to coordinate the work of the college with the work of the industries, and the industrial work of the lower schools.
PROFESSOR INDUSTRIAL ENGINEERING.
ASSISTANT PROFESSOR PRACTICAL MECHANICS. FIRST ASSISTANT AND SUBSTITUTE FOR PROFESSOR.
POLICIES AND METHODS SUBJECT TO ACTION AT DEPARTMENT MEETINGS
PRACTICAL MECHANICS.
OFFICE.
PROF. IND. ENG. IN CHARGE REQUESTS FOR REQUISITIONS SENT TO PROF IND. ENG. STENOGRAPHER WRITES DEPARTMENT CORRESPONDENCE ONLY, AND FILES SAME. DEPARTMENT CORRESPONDENCE DICTATED BY OTHERS THAN PROF. IND. ENG., TO BE SUBMITTED TO PROF. IND. ENG. OR ASST. PROF PRAC. MECHS BEFORE MAILING ASST. PROF. PRAC. MECHS IN CHARGE OF ALL STUDENT RECORDS
CONSTRUCTION.
INSTRUCTOR IN SHOP CONSTRUCTION IN CHARGE. RECEIVES DEPARTMENT ORDERS ONLY IN FORM OF PURCHASING AGENTS' STANDARD ORDER, EXCEPTING PERSONAL CASH ORDERS OR ORDERS FOR WORK FOR IND. ENG. DEPT. LAST NAMED ORDERS AUTHORIZED AT DEPARTMENT MEETINGS. HIRES ALL LABOR ENGAGED BY HOUR TO DO WORK FOR THE DEPARTMENT.
INDUSTRIAL MANAGEMENT.
PROF. IND. ENG. IN CHARGE OF COURSES I.E. 1, 3, 4, 5, 6, 8, 11. INSTRUCTOR IN FOUNDRY IN CHARGE OF COURSE I.E. 2. INSTRUCTOR IN SHOP CONSTRUCTION ASST. IN I.E. 6 INSTRUCTORS IN MACHINE SHOP PRACTICE IN CHARGE OF I.E. 7, AND ASST. IN I.E. 1.
INDUSTRIAL EDUCATION
INSTRUCTOR IN IND. ED. IN CHARGE OF COURSES I.E. 9, 10. ALSO SHOP 127, 143. SUBMITS PLANS TO PROF. IND. ENG. AND DEPARTMENT MEETINGS FOR DEVELOPMENT OF TEACHERS' COURSES AND EXTENSION WORK.
WOOD TURNING PATTERN MAKING
ASST PROF. PRAC. MECHS. IN CHARGE OF COURSES; SHOP SHOP 103, 105, 121, 122, 140, 201, 203, 230, 238. INSTRUCTOR PRAC. MECHS, INSTRUCTOR IND. ED. AND INSTRUCTOR IN WOODWORK TO ASSIST IN ABOVE COURSES
JOINERY AND CABINET WORK.
ASST. PROF. PRAC. MECHS. IN CHARGE OF COURSES; SHOP 101, 102, 133, 204. INSTRUCTOR PRAC. MECHS INSTRUCTOR IN WOODWORK INSTRUCTOR IND. ED. TO ASSIST IN ABOVE COURSES
MACHINE SHOP PRACTICE
INSTRUCTOR IN CHARGE OF COURSE, EXERCISES AND STUDENT RECORDS. INSTRUCTOR "Y" IN CHARGE OF PLANNING DEPARTMENT AND SCIENTIFIC MANAGEMENT FEATURES.
FOUNDRY
INSTRUCTOR IN FOUNDRY WORK IN CHARGE OF COURSES; SHOP 124, 125, 220, 230.
FORGING.
INSTRUCTOR IN FORGING IN CHARGE OF COURSES; SHOP 104, 120, 202, 207, 222, 236.
SHEET METAL WORK, PIPE FITTING, CHIPPING FILING.
AN INSTRUCTOR TO BE APPOINTED 1914 & 1915 IF FUNS ARE AVAILABLE, UNTIL THEN THE WORK MUST BE CARRIED BY PRESENT INSTRUCTING FORCE AS ASSIGNED BY PROF. IND. ENG.

Fig. 1. Organization Chart for Department.

Work of the Corporation Schools.

I do not by these remarks wish to belittle the work done by institutions doing work of a nature which in educational language is termed extension or continuation work. Our large educational institutions might well copy some of the methods of the corporation schools. This is especially true of the time devoted to their work by the directors of corporation schools as compared to the time devoted to their duties and the fitness for such duties of the trustees or directors of large colleges. Take for example the Westinghouse Electric & Manufacturing Company's schools. The policies and methods of these schools are controlled by a board having representatives from the manufacturing, the engineering, and the commercial divisions. I meet one or more of these representatives, besides members of the teaching staff, at every prominent engineering and educational convention which I attend. They are present at conventions of the national engineering societies, at the foundrymen's and metal trades manufacturers' conventions, at general educational gatherings, at state societies of manual arts, at social and economic gatherings, in fact everywhere where they can gain inspiration and new ideas. A member of the board was sent to Europe to study foreign methods of industrial education and corporation schools.

The shop apprentices who are receiving continuation school instruction are given questions and problems relating to the company's payroll and wage system, stores accounting system, etc., so that they understand them thoroughly. The college graduates receiving the special course for such men are given a broader instruction. For instance in the matter of wage systems they are shown blue-prints of curves and charts comparing practically all existing methods of remunerating labor, and are told why the company has selected the type of remuneration in each of the various departments, which is at present used. The Western Electric Company also gives excellent training to the college graduates whom they employ. It offers distinct courses of preparation for the commercial

and selling division, for the technical engineering division, and for the manufacturing and works management division.

Extension Instruction.

A large number of persons are being reached by education of the extension type offered by the various private correspondence schools. Training in scientific management is being offered by three types of correspondence schools; (*a*) The large correspondence schools which offer courses in diversified

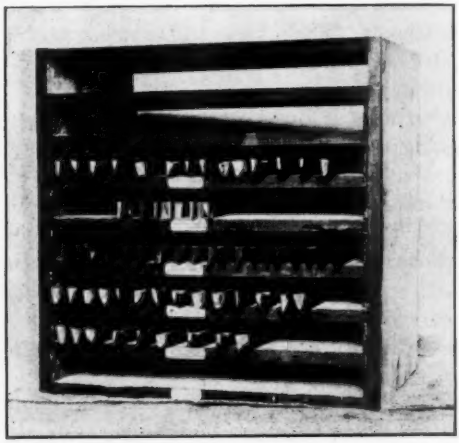

Fig. 2. Filler for Standard Tool-room Bin.

branches of sciences, trades, and arts such as the International and the American Schools of Correspondence, (*b*) the correspondence schools specializing in legal and commercial training, such as the Alexander Hamilton Institute and the LaSalle Extension University, (*c*) the specialized correspondence schools such as those organized by Harrington Emerson, Clinton Wood, and George F. Card.

To the work of these institutions must be added the extension work of the various local Y. M. C. A.'s aided by the Inter-

national Y. M. C. A. and the extension classes supervised by extension instructors from state educational institutions such as the University of Wisconsin and the Pennsylvania State College.

Correspondence Schools and Secondary Schools.

The work of the correspondence schools has been principally along the lines of principles of organization and management, commerce and finance, general accounting and manufacturing systems. The engineering features of industrial management are not as a rule included in the courses of instruction offered. Some of the monographs of these correspondence schools are excellent texts worthy of adoption in college work, and several of the correspondence schools have been sufficiently farsighted to permit the use of their texts by college instructors.

In secondary schools, otherwise known as public high schools, we find that scientific management is being adopted in some phases of manual training instruction. Several years ago I mentioned the use of applied methods of scientific management in a brief contribution to a publication circulating among manual training high schools, and received a number of inquiries from directors of manual arts for further information. There is no reason why certain principles of time and motion study, stores accounting, tool lists and tool-room methods, order of work and dispatching cannot be applied to this work, in manual training high schools along the lines we are following in our college shops.

Scientific Management Instruction in the Colleges.

When we come to consider the teaching of scientific management in educational institutions of collegiate grade, we will have to classify these institutions. In this group we have: (*a*) the classical or liberal arts traditional college intended as preparation for a course in a graduate school, (*b*) the college which aims to combine liberal arts with technology in a four-year course, and (*c*) the graduate school.

So far as the teaching of principles of management in the traditional college course is concerned, it will suffice to say that three hours per week in the senior year might advantageously be devoted to such subjects as economics of business during one semester, and organization and management in another semester; these subjects being taught by members of the department of economics, using such texts as Brisco's "Economics of Business" and Galloway's "Organization and Management." In colleges of this type we cannot expect the professors to have had practical experience in management, as the authorities usually prefer a man with a doctor's degree and no practical experience to a man with only a bachelor's degree and practical experience. More than likely, too, the professor will have to cover a wide range of branches in

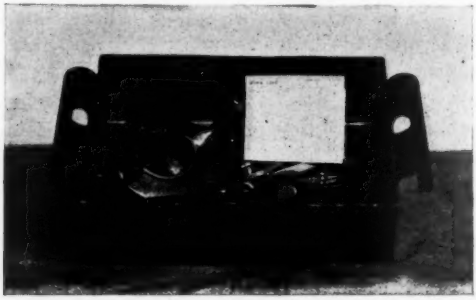

Fig. 3. Tote Box with Standard Set of Tools and Tool List.

the field of economics such as political parties, labor problems, international law, principles of economics, etc.

Coming next to the college which aims in a four-year undergraduate course to combine some instruction in liberal arts with a course in technology, we have two types of college course in which attempts are being made to teach scientific management, namely colleges offering courses in commerce and finance or business administration on the one hand, and colleges offering

courses in industrial engineering or business engineering or general engineering, on the other hand.

Scientific Management Instruction in Undergraduate Courses in "Business Administration" or "Commerce and Finance."

In the better grade of colleges offering courses in commerce and finance, and business administration the men teaching accountancy, money and banking, brokerage, and insurance are usually accorded professorial rank and salary and are, as a rule, men who have had actual practical experience in these fields. In these colleges, the teaching of management has been introduced as a sort of after-thought or recent development, largely as a result of what might be called the efficiency movement of 1911, which was largely the result of the widespread publicity given to Mr. Brandeis's utilizing the testimony of prominent engineers who had been instrumental in developing the modern science of industrial management, in the hearings before the Interstate Commerce Commission. In many of these colleges the teaching of management has been handed over to young men of instructor's rank, with little practical experience and no executive experience in industrial administration. In some cases this instructor acts as a guide to students who visit industrial establishments having a reputation for good management and acts also as manager of a series of lectures to be given to students by well-known business managers and industrial and efficiency engineers.

The graduates of schools of this type are usually well grounded in theory of accounts and economics of commerce. Many of them are eligible, after some years of experience after graduation, to take an examination for the degree of certified public accountant. None of them are eligible to the title of industrial engineer or efficiency engineer, since they have not been trained in the fundamentals of engineering and have not had the engineering experience which alone entitles the graduate of an engineering college, after he has received his

bachelor's degree and has had practical work for three years, to present a thesis and become a candidate for an engineering degree.

Teaching Management in Undergraduate Engineering Courses.

Coming to the undergraduate college courses in engineering, we need mention only in a passing way the "orthodox" courses in civil, mechanical and electrical engineering. The teaching of management in courses of this type is usually re-

Fig. 4. Students Taking Time-Study Observations.

stricted to a one-hour-per-week course in the second semester of the senior year.

In some institutions such, for example, as the University of Illinois, where the control of the shops is vested in a distinct department, headed by a man of broad education and experience, and receiving a salary higher than the average profes-

sor's salary in other institutions, a necessary inducement to secure this type of man, we see certain applied methods of management embodied in the shop instruction given to students taking the traditional engineering courses, and in this way they get some contact with modern management methods.

We must bear in mind, however, that approximately 40 per cent. of the membership of the American Society of Civil Engineers consists of men engaged as executives in manufacturing or contracting work or in business for themselves as consulting engineers; about 50 per cent of the membership of the American Institute of Electrical Engineers comes under this class, and about 60 per cent of the membership of the American Society of Mechanical Engineers belongs to this group. We must also bear in mind that pretty nearly all of the best literature and noteworthy practical work in scientific management has been the work of engineers with no other direct training for management than their actual contact with men, machinery, methods, markets and money.

The Problem of Preparing Young Men for Management Work.

It is very apparent to engineers who have achieved success in management that the average graduate from a school of engineering is confronted less often by problems requiring ability as an inventor than he is by problems requiring familiarity with principles and applied methods of industrial management. Young men who have completed undergraduate courses in business administration or in commerce and finance may be well grounded in sciences and arts relating to men, markets and money; but machinery, methods of production, and the lay-out and service equipment of industrial plants are engineering features of industrial management so interwoven with the human and economic and financial features as to make it a matter of grave doubt whether the industrial field is a fit one for young men who have completed only an undergraduate course in business administration or commerce

and finance. In my own practical experience in installing methods of modern management in large manufacturing establishments in Cincinnati, Indianapolis and Chicago I have had occasion to place side by side young college graduates from various institutions and graduating from courses in business administration on the one hand and in engineering on the other. I have found that the engineering graduates were as a rule unfamiliar with business practice, accounting and economics, while the business administration graduates were ignorant of manufacturing and engineering, and were inclined to be insufficiently interested in the faithful plugging type of task assigned to young men of all classes. The engineering course men were usually the only ones who could be assigned to time study, and planning department work. The business administration men usually were able to handle work in connection with employment and welfare problems, and statistics.

COURSE IN MANAGEMENT AT PENNSYLVANIA STATE COLLEGE.

Eleven years ago, at a convention of the Society for Promotion of Engineering Education I presented a paper on the subject of "Education for Factory Management" in which I advocated the teaching of principles and applied methods of management in an engineering course. It was evident from the discussions of this and subsequent papers along the same line that the only manner in which training in management could be given in undergraduate engineering courses was through the medium of an entirely new course in which economics, psychology, principles and applied methods of management took the place of some of the more technical features of the designing and testing of the existing engineering courses. In 1909 we established our four-year course in industrial engineering at the Pennsylvania State College along these lines. This course contains all the fundamental mathematics, underlying science and mechanics given in the standard engineering courses, but in place of the more technical work in designing and testing we introduced work in organization, manage-

ment, theory of accounts, factory accounting, foundry and pattern-shop methods and organization, machine-shop methods and organization, factory lay-out and design and the application of such methods of scientific management, as planning department including orders of work bulletining, making of time studies, preparation of instruction cards and tool lists, keeping of cost records and accounts on commercial work actually sold on the one hand and certain essential exercise work on the other hand. The degree obtained by students graduating in this course is that of Bachelor of Science in Industrial Engineering.

Training for Teaching Management.

When I was given jurisdiction over this course I felt that my experience as an engineer, superintendent, and consulting expert, while all very well from a practical standpoint, might

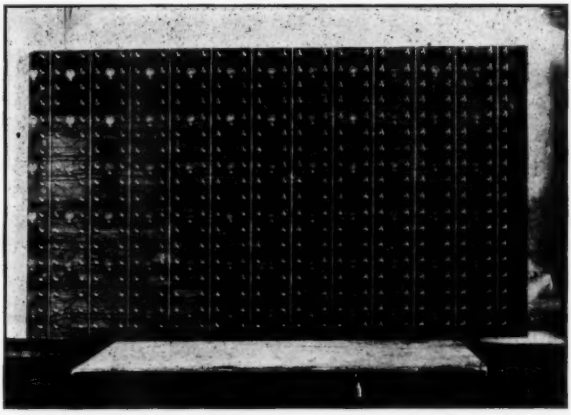

Fig. 5. Office Bulletin Board.

still leave something to be desired for in the way of theoretical training. Hence, I voluntarily undertook to attend, as a regular student, the classes and examinations necessary for an

undergraduate degree in history, economics and political science, taking such general liberal arts course as psychology, logic, and all of the course in theory of education offered at the Pennsylvania State College. I deliberately subjected myself to the drill and discipline of this undergraduate work because I wanted to secure anything that the graduate of a course of this type might have which was not obtained by an engineering graduate. I heartily enjoyed this work and only wish that all engineers could take work of this character. I am still more powerfully convinced as a result of taking this course, however, that even the most inspiring instructor, possessing the benefit of the doctor's degree and extensive foreign travel, but without experience in industrial management, cannot take the place of the trained and experienced engineer in teaching management. From a cultural and scholastic standpoint the practicing engineer has gained something quite as important and of totally different character than the liberal arts graduate with his Ph.D. and foreign travel.

For these reasons I do not believe in a graduate course devoted exclusively to technical engineering in a graduate school in which the engineering professors are technical experts and in which there are no experienced engineers teaching management. This teaching in industrial management cannot be given by classicists in undergraduate or graduate colleges of business administration in a manner which will meet the needs of the industries.

Graduate Schools of Business Administration.

These considerations bring us to the graduate schools of engineering and business administration. So far as concerns graduate school courses in insurance, transportation, salesmanship, accountancy, consular service and diplomacy, the standard undergraduate college course constitutes a suitable preparation. When it comes to a graduate course in industrial engineering, however, the undergraduate college course

is, figuratively speaking, a wall or dam between the high-school training and the final training. In order to prepare for a graduate course in industrial engineering, there should be a continuous and widening stream of technology right through the undergraduate college course. No such opportunity is offered in the inflexible system of the big universities which do not permit the dovetailing of the studies in the completely segregated graduate schools of engineering and business administration on the one hand and the undergraduate colleges on the other hand. In order to obtain the necessary fundamentals in economics and engineering it would be necessary for a man to complete all three of these courses separately, and then he would still be without direct teaching in principles and applied methods of scientific management by an engineer with actual experience in industrial management.

Practical Suggestions for Existing Schools.

So far as existing schools of engineering are concerned, I am firmly convinced that we can prepare best for industrial management in the following manner. Separate shop-work from mechanical engineering. Employ an engineer with management experience and put him in charge of the shops. Pay him the salary necessary to secure a man of such experience. This will be higher than average prevailing professional salaries. Establish a distinct course in industrial engineering, separate from the existing engineering courses. Such a course will prepare for a field which statistics show is the actual field of employment of half the members of all the national engineering societies. Put the man who was made head of the shops at the head of this new course. Give him sufficient financial support in this department so that he can employ in his shops men of the same experience and calibre as would be eligible for foremanships in the industries. This means that salaries of from $1,500 to $2,000 per year must be paid to the instructors in these shops, irrespective of whether they have had college training or not. If less is offered we cannot secure

the trade-skill and experience necessary. We must supplement these instructors by a planning department manned with instructors having had actual planning-department experience. When we remember that planning-department help is largely recruited from the ranks of foremen, we can see that here again we cannot be hampered by the traditionally low pay accorded to men who would doubtless be classified as assistants in administration if designated by the classification current in existing college organizations.

Proposed Joint Committee on the Title Industrial Engineer.

It is evident that we are confronted by conditions quite revolutionary so far as present standards of teaching are concerned, and we cannot meet these conditions by applying the old methods.

I have been asked for an opinion of the training, ability and experience required of a man who could legitimately style himself an efficiency engineer or an industrial engineer, to pave the way for further discussion of this question.

In reply I would state the following requirements as recommended conditions precedent to the conferring of the title of industrial engineer:

1. Eligibility to full membership in one of the national engineering societies.

2. At least three years of experience in responsible charge of some phase of industrial management work.

3. The ability to pass an examination in industrial accounts with full reference to the interlocking of manufacturing accounts with the double-entry accounting system.

I would suggest as the personnel of a committee to determine the right to use the title industrial engineer, three men from the committee of management of the American Society of Mechanical Engineers, three men from the Society for the Promotion of Engineering Education, three men from the Society for Promotion of the Science of Management and three

men from the Efficiency Society of America. This committee of twelve might be allowed to waive the examination in accounting in the case of applications from men who had done such work in systematizing and other higher classes of accountancy as in their judgment made an examination unnecessary.

This committee should by resolution disapprove of the use of the title of industrial engineer or efficiency engineer by members of firms of expert book-keepers or auditors who have for advertising purposes adopted the new titles without being able to meet the requirements herein set forth.

STUDIES IN PROBLEM DESIGN.

BY H. H. HIGBIE,

Professor of Electrical Engineering, University of Michigan.

It is probably not disputable among teachers of engineering, that problem work is valuable to the student; nevertheless it is quite certain that its full value is seldom realized, and that by special study of the possibilities of problems in any course of instruction, there may be developed qualities of strength, interest, and inspiration that increase the efficiency of teacher and student. Some of the results which may follow, directly or indirectly, from a special study of the principles of design and construction of problems for engineering students are enumerated below. No attempt has been made to arrange them in the order of their importance, as there may be a reasonable difference of opinion on this point.

Fundamental Purposes of Problems.

1. To excite and sustain the interest and enthusiasm of the student in the courses of study laid out for him; to energize him and render these forces dynamic.

2. To concentrate the attention of the student upon important matters which the instructor desires to emphasize; to create respect for some features likely to be slighted, and to destroy undue fear with which he is likely to view other features.

3. To show that useful, important results of practical value may be deduced by simple methods from simple data, easily obtained; that is, to develop engineering common-sense.

4. To show that an apparently simple question may be really difficult to answer correctly; that an apparently hard question may be really easy to answer, and that almost any question may be answered by patient work, if not merely by the exercise of a little common sense; to make the student less diffident and more ready to tackle new problems.

5. To show the relations existing among the sciences, or among the various courses of study where they are in contact, and among the interdependent laws and facts in the course; to give the student perspective.

6. To develop in the student methods and habits of thinking, a logical sequence of ideas, and a quick sensitiveness to numerous delicate in-

fluences which enables him to trace his way rapidly in as straight a line as possible from the data given to the correct conclusions deducible therefrom, or from a result desired, back to the fundamentals involved, or to notice as quickly as possible when he has strayed from the right path, and to get back to the straight path as quickly as possible; in other words to get his "bearings" quickly, and to keep them always, so that, regardless of how or where he may be thrown, he will be able to land on his feet and *start to move* in the right direction, immediately.

7. To develop a kind of judgment and a sense of values in weighing data, methods, and information, in selection of the good and pertinent from the bad or irrelevant, and in the comparison of various sources of information as to accuracy and consistency.

8. To show the use and value of references, where to look for information that may be necessary, how to recognize "pay dirt" when it is turned up, and how to break it up or to concentrate it, if it is not found in chunks of the proper size. To give practice in the transformation or translation of data from one form to another.

9. To develop originality and ingenuity in the student, or to foster them where they already exist; to teach him independence and resourcefulness, to destroy the formula-habit or the desire to force new solutions to follow old precedents; to render him sensitive to variation of conditions, and ready to take advantage of new situations.

10. To show where more information is needed than is at hand, and the form in which it should be obtained to be most useful; to develop an interest in research and original investigation. In fact the student is likely to contract the *problem disease* from the instructor, and to continue to ask himself new questions and to seek new meanings in old and well-known phenomena even after the stimulus is removed, with the result that a new investigator is born.

11. To develop an ability to translate written specifications into mathematical forms and equations, or to feel and express the real meaning of the result of a mathematical process; to open up the field of mathematics by developing a realization that it is logical and understandable as well as mechanical and usable; to show how to write mathematics from English, and to talk English from mathematics.

12. To give confidence in theory and in the capability of the mind, as well as a knowledge of its limitations; and also, to emphasize the necessity for *experience factors* obtainable only by observations in practical and experimental work. To show how much of useful results and information may be obtained, often, from very few data; also, to show how very many data and much experience are necessary to formulate a generalization, and how many facts may follow from a given law.

13. To develop habits of caution and of accuracy, and yet to moderate any undue sense of either; to point out the possibilities of error, methods

for checking results, the value or valuelessness, as the case may be, of great refinements or of rough approximations.

14. To enable the teacher to adjust the task of each student to his individual abilities, interests, and limitations; to make him do his best, to develop him where he is weak, to excite new interests by suggestion; and all this without confusing or discouraging the weak man, or giving the strong one opportunity and incentive to "soldier" or "mark time."

15. To relieve the monotony of the teacher's work. He keeps going over the same fundamental ideas with successive classes, to be sure, but the flexibility of problem work enables him to take a great personal pleasure in the development of new material, and in the intimate study of development of the student mind in response to this problem work.

16. To develop and educate the teacher through study of design and construction of problems. There are many points to be considered, and the number seems to increase perpetually. Some information must be given as a foundation for each new problem, which necessitates search for new data, or search for new facts which may be descended from old data, or the fitting together of related data. The information must be stated in proper form, to achieve certain of the purposes outlined above. In some cases, the wording and form of stating the information and the questions founded upon it, must be worked out in proper logical sequence so as to guide the student, while in other cases this may be just as studiously avoided. A veiled answer may be prepared in the statement of the problem. It may be desired to avoid contradictions in the data, or to give either too many or too few data. The phrasing must be direct, clear, forceful, concise, interesting, skilful. The student should frequently be led to finish a problem with some additional questions of his own devising, on his own initiative. In fact, the teacher ultimately gets himself into the habit of designing the problem fully in his mind, determining the form of the data and the questions, and examining its possibilities from the viewpoint of the student, all before it is formulated on paper or on the blackboard; and this makes the very best kind of mental gymnastics. All of this leads to the development of great breadth of view and very active, rapid, incisive habits of thought on the part of the teacher, and furnishes a limitless field for the exercise of his desire to do practical work, as distinguished from pure pedagogy.

Problem Designing.

It would be vain to seek, in any single problem, an opportunity to realize all of the possibilities enumerated above; but if these points are kept in mind while a whole series of problems for a course of study is being devised, it is possible to

bring them out. Some of them involve the development of habits, and this requires repetition of related experiences; others involve stimulation of the student, which presupposes that he has some interests or abilities which make him responsive to such stimulation. And in all of this work, the element of time is very influential; the student must have opportunity and encouragement to do his work carefully, thoughtfully and as slowly as his temperament requires for proper assimilation. The idea of definite and exact prescription of the content of a course of study regardless of the individual student, must be renounced as human beings differ so widely. Every one of us desires to take pleasure in his work and to make the most of the particular abilities with which Nature has endowed him. We do not want to be all alike, anyway, even if the application of force could accomplish such a result.

It would be difficult to write, or to cite, within the space-limits assigned to this article, a set of problems which should illustrate every one of the features outlined as being possible of accomplishment by study and analysis of problem design, particularly as the subjects which would interest one teacher would not interest another. If the idea of designing problems with such broad yet definite objects in view meets with approval, it may be possible, through discussion among engineering teachers, to create a set of problem models along a number of different engineering lines, having skeletons built upon correct anatomical principles and classified in proper order of development, and so devised that any skilful teacher may quickly change the clothing and the setting while retaining the same essential form.

Sources of Problems—Text-books.

In almost any course of study which may be mentioned or devised, it is quite possible to collect from text-book literature a fairly comprehensive and coherent set of problems; but an analysis of all of the sources with which the writer is familiar indicates that in most text-books the problems are designed particularly to illustrate specific points in the text. The text

is designed to impart information or to exhibit relationship existing between facts and occurrences and the whole treatment usually regards the *object* of the study, to the exclusion of the *subject* who is to be taught. Our interest, as scientific writers, is too likely to be concentrated on *things*, and not enough on *men;* yet it is more important for students to have their minds and characters trained to orderly and logical methods, common sense and self-respect, than to have their brains filled with facts, figures, laws and other information. Authors of engineering text-books should seek to develop engineers, *men*, rather than engineering, *knowledge;* because, after the attributes of the real man are developed, knowledge will be perpetually sought and obtained as it is needed, whereas the knowledge without the manhood is unproductive. Problems are a sort of fluid medium in which the attributes of manhood may be cultivated to best advantage.

The very word *problem*, whether it relates to morals, science or art, conjures up before the mind a picture of a mental strife, a warfare between opposed impulses or methods, a process of fighting things out and coming to a definite conclusion by the exercise of one's own personality; and certainly it is in activity and strife that self-confidence and ability are developed, rather than in passive attention to lectures, precepts or examples. The real student, the interested one, welcomes a problem because it is an opportunity to test himself, to see what he can do with the information he has acquired, or to find whether he really understands the law as he thinks he understands it. May we not imagine that sometime a complete text shall be written for college students containing nothing but problems? Ordinarily we find an abstract statement of knowledge, of facts or laws, a paragraph or chapter, followed more or less closely by a more or less intimately related set of problems to exercise the student in the use of this knowledge. The teachers seem to have conceived their function to be, first to dissolve the most important things, the fundamentals of a profession, then to add to the solution some

pedagogical study or research which makes a separation of principles and theory from practice and applications, the former coming to the top as a clear but bitter essence, the latter sinking to the bottom as a sugary-looking precipitate. We try to make the student swallow this preparation, liquid first and then precipitate. We should get the same or better results, more quickly and easily, by keeping the stuff *stirred up*. Perhaps time and effort would be economized, for student, author and teacher, if we were to omit altogether that which, in the ordinary sense of the word, *is* the text; and to develop the students' personality and knowledge solely by the use of problems and examples, arranging each to carry a bit of knowledge and a suggestion for thought, and by its relation to the other problems, to contribute its share toward the habits and traits of personality which it seems desirable to develop. Some problem books are already in print, but no one of them can be said to be a text which may be used without accompaniment of some supplementary descriptive and theoretical material and none appears to be designed for the consistent, continuous development of the student.

Problem Structure and Administration.

Considering the application of principles already laid down, we may classify the details as follows:

A. Structure of the problem; methods of stating data and of asking questions.

B. Methods of assigning problems and of evaluating the students' work.

C. Sources of material available for use in problems.

First, in every problem there should be a useful object; preferably so clearly defined that the student can appreciate it by reading through the statement before starting to work; or, that the arrangement of the several problems in a group or of the several questions in a given problem, be such that the reasons for setting each task appear always a little in advance of the work. In general, the motives inducing any of us to work are reducible to two fundamental ones, namely

necessity and *pleasure;* and of these two the latter is undoubtedly the one we must rely upon in school, to secure the best results from youths who are not subjected to economic pressure. Undoubtedly we get the greatest pleasure and gain from intellectual work when we understand what we are "driving at," and are not merely proceeding blindly according to directions, or in desultory fashion hoping to turn up something. A problem should never be allowed to appear to a student merely as an *exercise;* some "mollycoddles" there may be who prefer exercise to real, useful work, but most young men have a very keen appreciation of what real life-work is, and they want to get at it as directly as possible. Before they will expend funds, energy or materials, *engineers* always ask "what is the object of this expenditure, and what are the prospects of getting returns?" So, perhaps, it is well for teachers to allow engineering students to indulge the natural inclination to ask just such questions concerning their work in college. By being careful about the kind of problem he assigns, the teacher may train the student to a habit of thinking only about things worth while.

Second, every problem should carry with it a little real information or data, or interpretation of some law or phenomenon, plainly stated in relation to the work which is proposed for the student to do. Data in the pure concentrated unadulterated form, boiled down as in an engineering report or a handbook, a table of figures or a set of curves, may be entrancingly beautiful to the expert or to the statistician; but in such form its possibilities are hidden to the average undergraduate student. To make these visible to him, the raw information must be split up or polished, interpreted. Moreover, when information is once *used,* as in a problem, it is not so easily forgotten, and is more easily used when the next occasion calls for it. The student should be led to have faith in the utility and value of his problems, by basing them upon real measurements and reliable observations as far as possible, so that he may come to regard them as sources of knowledge just as much as or more than the lectures or his text-

books, rather than merely as exercises to gain proficiency or to prove his knowledge to the teacher. Frequently, a studied wording of the statement of the problem will enable the student to see light upon matters not involved in the questions asked in the problem, or will suggest new questions to the thoughtful student.

These two points ought to be involved in every problem. In addition there are other points which it may or may not be desirable to work into the problem, depending upon the nature of the subject and the state of development of the student; some of these points are mentioned in what follows.

Problems for Beginners.

With students who are beginning a subject, it may be desirable to indicate with sufficient clearness the proper steps to be taken to pass from the given data to the desired conclusion. This may be done directly by giving, in more or less detail, definite directions for procedure until an answer is reached; or indirectly, by asking partial questions in succession along a line of logical procedure. In some cases, a solution of the problem may be given by the teacher, and the student asked to pick flaws in this solution, or to check the given solution by working the problem independently along some other lines of procedure.

For beginners the data should be carefully selected and prepared, so that their attention may be concentrated upon one point at a time. But as soon as practicable, an opportunity should be made to give the data in such form that they cannot be used directly; that is, an excess may be given, so that the student must select wisely; or a deficiency, so that he must seek more and determine exactly what he needs; or contradictory data, so that he is led to discover the inconsistency; or data in inconvenient form or in foreign units, so that he is compelled to translate before he can use them. In this connection also, there arises an opportunity to make problems *comprehensive*, each involving not merely an isolated piece of knowledge which it is desired to "drive home," but also

requiring the understanding and use of other information which has been previously treated in detail. I do not favor problems which are retroactive in the sense that they depend upon the answers of previous problems or questions, because this leads frequently to serious inconveniences; but I do favor having at least some of the more advanced problems designed so as to compel the student to draw largely from his previously acquired store of knowledge. The tendency is altogether too pronounced in our educational system to create sharp artificial boundary lines between different sciences or even between different specialties in the same science; and the student too frequently fails to realize that it is possible and permissible to use, for example, at 11:05 A. M. in an engineering classroom, certain information which he absorbed in the preceding physics class at 10:55 A. M. Too often an apparent ignorance on the part of the student is due simply to his failure to realize the availability of the knowledge which he possesses; nobody has shown him how to use what he has, nor how to search his brain for something which he may press into service in emergency. Each bit of information, as received, is carefully wrapped up, embalmed, and stowed away in a brain cell hermetically sealed from every other brain cell, and never resurrected until the conditions under which it originally flourished are exactly reproduced, which may be *never*. Problem work, under the direction of competent and versatile teachers, may be used more effectually than any other means to destroy any such artifical boundaries or any hoarding habits to which the student may have been addicted, and to keep him ready to use anything he knows at any time, provided only that it be true and applicable.

For beginners, it is also desirable to make problems short and easy, the object being to develop confidence and speed. It is exhilarating for the student, to think that he is going fast; at the same time, he gets practice and drill in plenty. Certain problems are adapted to being recast many times in different fashion, changing perhaps the form of the data or the units of measurement or the object to which the problem is ad-

dressed, while retaining the same operations, relationships or trains of thought. Some students can go farther in a given time by a large number of short steps taken continuously with increasing rapidity, than by a small number of broad jumps which require them to stop and collect themselves before and after each.

Series and Groups of Problems.

There is sometimes an advantage in making a group of problems continuous, in founding a whole series of questions upon the same set of data. Besides giving an opportunity to demonstrate the advantages of carrying an inquiry down to minute details or forward to an elaborate conclusion and to show the relations of several factors to each other, such problems tend to create an appreciation of the large results which may be secured from given premises. There is also a practical advantage in that the students' time is economized by avoiding the confusion and readjustment involved in changing from one basis of thought to another. In other words, if we have, say, four related ideas which we desire to bring out by problems, it is often better to arrange a single set of data to serve as a foundation for all of these than to base each on a different set of data. Most people have sufficient mental "mass" to be troubled by inertia reaction. That is, it is difficult to start rapidly in a new line of thought, and usually equally difficult to stop thinking along it after they have speeded up. Of course, it would be desirable to reduce the mass if it could be done without sacrifice of penetrating power, to make up in acceleration what is sacrificed in mass; because, other things being equal, the man who can get from "scratch to finish" in the shortest time is the winner. Therefore, it is proper in the more advanced problem work, to make the ideas quite diverse in a group of problems or in a single problem, so that a student becomes accustomed to picking up an idea rapidly and dropping it, turning corners or looking forward or backward without stumbling, while he is running, and being generally

able to keep his poise and adjust himself rapidly to any change of conditions.

An idea which I have had in mind but have not had opportunity to practice or develop, is to arrange some problem work for the more advanced students, like the mental arithmetic exercises we used to have in grammar school. After a series of problems illustrating certain principles has been worked out in careful detail to exact answers, another similar set would be given in disguised form, the student being required to work them as rapidly as possible, not to obtain answers but to formulate methods of solution, possibly even to go so far as to write down the equations or to draw diagrams, but at least to state to the instructor what steps should be taken, and in what order. College men are generally fairly well trained to give deep and careful consideration to all the fine technical points of a problem; but very often they find when they come to apply their knowledge that there is a distinct advantage in being able to grasp an idea or a situation quickly and comprehensively, to decide rapidly what is essential and what is non-essential, to find whether there is enough information to work upon and if not what is lacking, to survey the problem and draw a mental line between the information given and the result desired so as to be able perhaps to give an opinion whether a proposition is even feasible, or perhaps to set subordinates at work usefully, harmoniously, and efficiently to coöperate in a definite and complete solution. In some cases it is even feasible to divide a class into squads of convenient size, and to appoint one man in each to be "chief engineer," his duty being to direct the work of the other men, to collect and prepare the information for a report upon a proposition, and to be responsible for the volume, rapidity, and accuracy of the work done. He may be called upon to present as quickly as possible a preliminary report proposing several rough plans with an opinion as to their relative value, and later he may be given the task of carrying the selected plan through completely. In any event, it is well worth while to

arrange the problem work to develop rapidity as well as accuracy.

Fostering a Critical Spirit.

It is well to arrange some problems with a view to fostering a critical and debating ability in the student. Two plans to achieve a single result may be presented to him in sufficient detail, and he may be asked to give an opinion as to their relative value, and to support his opinion by arguments. Or an advertisement, claiming certain results for a device, may be clipped from a technical paper, and he may be asked to prove whether these claims are reasonable or unreasonable. Or, two catalogs may be given him, each claiming to show by data a superiority for a described device, and he may be asked to weigh the claims against each other and to find the errors in them. Or he may be shown a text-book, a catalog, or a specification, in which the statement is ambiguous, and he may be required to state the correct meaning and to give reasons for his opinion. I have tried numerous plans like these, and have found that they increase greatly the interest and self-confidence of the students, and open their eyes to new sources of information, rendering them also sufficiently circumspect to use such information safely.

Administrative Details.

Consider now some of the methods of assigning problems and of evaluating students' work. Opinions and practices of teachers differ widely here, but it is generally conceded that problems are particularly useful as home-work for students, to illuminate the lessons; and also as material for class quizzes, written or oral, at bench or at blackboard, to inform the teacher as to the student's progress, his difficulties, his knowledge and his ability. It is not so generally conceded that problem work should be *regular,* that *every* lesson, as nearly as possible, should be accompanied by problems showing the bearing of the information upon various real conditions. This regularity tends to discipline the student's mind, and to habituate it to inquiry and introspection, to getting the by-

products out of every theory and every description studied or read. Before long he will be surprised and delighted to see how much good "juice" he can squeeze out of even the driest cactus-like theoretical proposition or text. An engineer's principal business is to solve problems, to take data from one process or structure and use them in whatever form may be necessary, to project and carry through to successful conclusion some other process or structure. His business is in making reasonable predictions, and in collecting information which enables him to make them. We should, therefore, try to develop in the student the habits and mental discipline which will enable him to go into this work easily. Habits and discipline can only result from regular repetition of real efforts.

Perhaps too, we shall agree generally that students should be urged or compelled to rely upon their own efforts, as far as possible. The writer believes, however, that some latitude should be allowed. In my teaching, I do not attempt to measure a student's attainments from any written work done outside of the classroom; I explain clearly to him, at the beginning, that such work is intended purely for his benefit, and is handed in by him to be corrected and returned principally to aid him in locating and overcoming his difficulties. A record of the quantity and quality of the problems solved is kept, however, to guide me in estimating the interest and effort displayed. Estimates of ability and accomplishment are based principally upon numerous recitations in class, with frequent formal examinations. It should be stated that, in this system, the main purpose of every session in the classroom is to clear up the student's difficulties, and to uncover his ignorance for the purpose of remedying it, not of grading him. At most of the recitations, an opportunity is afforded for any student to ask for the solution of any of the home problems in which he could not satisfy himself, and his request is considered *bona fide* if he is familiar enough with the details of the problem to be able to state exactly how far he got and where he ran into difficulties. The teacher may call upon some one who did

work the problem to write the solution upon the blackboard, or he may write it himself, quizzing as he proceeds. A scheme which has been used successfully to get a recitation from every man in the class simultaneously, while teaching, is to write upon the blackboard a problem or a related group of problems, the students, copying them meanwhile in loose-leaf notebooks. The students then proceed to give their solutions of the problem, their writing being duplicated in the notebooks by use of carbon sheets. The problem is designed to occupy the average student for, say, three quarters of the period. At the end of this time, the instructor collects the original sheets and proceeds to explain the correct solution at the board, while the students make corrections or additions to their carbon copies. He can examine and grade the solutions at his convenience, while the students are able to check their work immediately, with the details fresh in mind. Furthermore, they are frequently surprised to see how easily and quickly their troubles may disappear when subjected to the proper methods of treatment. Most problems are devised so that they are really exercises in *thinking,* and not in mathematical manipulations; usually they cannot be answered by mere substitution of given values in a formula from the text, nor can they be found duplicated exactly in any reference book. Usually the students are allowed to use any texts or references or notebooks they may have, but conversation is prohibited.

Developing a Sense of Responsibility.

With regard to their home-work, it is impressed upon the students that the man most highly prized in the profession is the one to whom a task may be assigned with assurance that he will not be heard from again until the job is done, and that in the best possible way and in the shortest possible time. They should not come back for further instructions until they have exhausted absolutely all the means they know for helping themselves, and should never seek help on mere suspicion of difficulties. It is perfectly legitimate for them to ask and receive help from each other before they go to the instructor.

When one conscientious student seeks help from another because he has no other resource, it does absolutely no harm, only good, because in giving help, the better man always discovers things which he did not see before, and he becomes more proficient in expressing himself and perhaps in argument, and he revises and fixes his own knowledge. The weaker man not only gets the help he needs just when he needs it, but he is likely to ask questions more frankly of his classmate than he would of his instructor, thereby laying his foundations more securely. Students will always work together anyway, regardless of any strictures which the instructors may pronounce upon such action; and even if no man's work were thereby improved or if some one's were given a fictitious value, there would have been developed some spirit of coöperation. It is always easy for an experienced teacher to demonstrate to students that they might as well be honest, and to give them plenty of opportunities to air their ignorance unsuspectingly.

Evaluating Student Efforts.

There will always be some argument on the question of giving students credit for methods and ideas, or for plain given conditions and the desired result into the form of a duty toward the students, not preparing them to be judged as their employers will judge them. Every engineering problem involves two distinct processes; first, the interpretation of the accurate *results*. There are sound bases for either contention, and the truth is probably somewhere between. The man who argues for exact results only, should never quarrel with the means employed, should never discourage the use of formulas by the student, and should be classed with the man who believes that every prisoner acquitted is innocent and every one convicted is guilty. He who regards the methods employed, without penalizing errors in calculation, is not doing his full mathematical equation, and second, the performance of the more or less mechanical process of solving this equation and arriving at a definite answer. Neither part should be sepa-

rated from the other, as both are essential. Experience nearly always shows that it is more difficult to get men who can do the former well, than the latter. If either part is emphasized the writer believes it should be the former, because that is where engineering students are likely to be weak, in the interpretation of science and the English language into mathematics, and not in the mere performance of mathematical processes for which exact rules are available. We should not necessarily grade a problem as perfect if the correct answer is obtained, even when this is accomplished by use of the correct *formula;* neither should we ever grade it as perfect if the correct reasoning is exhibited and a wrong numerical answer obtained.

Material for Problems.

Consider briefly, in conclusion, the sources of material available out of which to build problems. These may be:

1. Any text-book, or lecture-notes. The author of a text-book is not the only man qualified to write problems for his text. In every paragraph, in almost every sentence of a good technical book there is an inspiration and an opportunity for a problem, if the teacher tries to see it and cares to take advantage of it. Many good books which have been pressed into service as texts do not contain any problems worth mentioning: others contain a few, written to illustrate particular points, but without any idea of furnishing a thorough course of training and discipline. Sometimes the problems are all concentrated into an appendix at the end of the book and sometimes each chapter is followed by a group relating to the material in that chapter; but the scheme which works best, in my experience, is to have each new principle or paragraph accompanied by a small group of problems with, perhaps, an example to illustrate the method of solution; a longer group of problems following each chapter and relating to all the material in it without discrimination. Placing the small groups in contact with the explanation of principles underlying them gives a clue to the solutions. This is not a disadvantage, however, because the purpose of these problems is to

develop proficiency by reviewing the same idea in different relations, and the wording may be varied to sustain interest. One important object in having the large list of problems at the end of a chapter, is to force the student to choose his own references and methods. Such lists are therefore particularly suitable for reviewing the chapter.

2. As has already been mentioned, very interesting and valuable problems may be based upon the data contained in manufacturers' catalogs, or upon the claims made in catalogs and advertisements. Incidentally, such problems teach discrimination and confidence in the use of such material. Modern technical advertising may be quite valuable when properly used, and there is the advantage that manufacturers are always glad to furnish plenty of it to students in engineering colleges. The illustrations are likely to be better than those found in most text-books. In this connection should be mentioned a valuable scheme devised by Professor King, of the department of practical mathematics at Wentworth Institute. He cuts from a manufacturer's catalog the clearest picture he can find of a given machine or part of a machine, together with the printed catalog description of it, how it operates, what is claimed for it, and any tables, curves, and data furnished. These clippings are glued to one side of a piece of heavy book-binder's board (usually letter size), the corners of which have been dipped in shellac to avoid fraying. On the other side of the card is pasted a typewritten sheet containing a series of questions that may be answered from the pictures and data. The questions are numerous and varied, and graded in the order of their difficulty. A great variety of catalogs and subjects are so treated, from machine tools, gearing, belts and countershafts, to steam engines, blowers, dynamo machines, and electrical fittings. Whether he goes to meet a class in mathematics for students in electricity, in mechanics, or in strength of materials, or in any other subject, he selects from his stock of cards subjects appropriate, valuable and interesting to them. Each student gets a card, and an assignment to a problem on that card such as he needs, one

that is difficult enough to make him do his best, but not so as to make him fail. Nearly every student works upon a different problem, therefore all of them are compelled to work independently. The interest seems to be increased, also, by this fact. The teacher spends his time going around the class and giving help and advice where it is needed. The time which students frequently are required to dissipate in making poor sketches at the blackboard (exercises that cannot be claimed to improve their ability as draughtsmen), is now spent to better advantage in thinking about the problems and in getting results. To me this seems an ideal way to teach practical mathematics, and to possess many features which are applicable to almost any course in engineering. I have used catalogs in much the same way in my own classes for a number of years, with good results; however, I induce the manufacturer to ship enough catalogs so that each man in the class receives a copy which remains his property, and he is shown the advantages of using these catalogs as the nucleus of a collection.

3. Problems may be based upon data in the transactions of the various national or local engineering societies or institutes, and in current technical periodicals and literature. For undergraduates, references may be given in the problem to the exact volume and pages where the necessary information is to be found; but the advanced student may be given a roving commission and required only to state, in his solution, the exact locations of the data upon which it is based. The principal value of this method of founding a problem is to bring out prominently the great variety of sources where valuable knowledge may be found, and the importance of keeping in touch with these sources. The reference habit, once started as a partial requirement in a course of study, is likely to prove so pleasant and useful that it is permanently retained.

4. Problems may be based upon the results of experiments and tests which the student himself has performed as a part of his regular laboratory work, or tests which have been performed as thesis work, or by the instructor himself. The stu-

dent may be required to run down inconsistencies, and to show the reasons for them.

5. Some problems may require the student to formulate a set of facts or relations presented to him as a table of corresponding values, or as a specification or description; or require him to state in words as fully and clearly as possible the significance of a formula or a set of curves placed before him. For instance, he may be given a formula showing symbolically the relations between per cent loss of power, cross-sectional area of wire, length of wire, amount of power transmitted, and voltage between wires, for an electrical transmission line, and be asked to write down as clearly, distinctly, and concisely as possible all of the ways in which the advantage of a doubled voltage may be taken.

The subject of problem design has been treated generally rather than specifically in this paper, because it seems to be in their general relations to each other and to the education of the student that problems most lack perfection and polish. Usually problems are considered to be merely adjuncts to a text-book. Perhaps if we can agree that problems are the chief concern of an engineering education as they are the chief business of an engineer, we may be willing to accord to them the study which they deserve.

THE PRECEPTORIAL SYSTEM, AND ELECTRICAL ENGINEERING AT UNION COLLEGE.

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The Princeton System.

Princeton's greatest contribution to education in recent years is the preceptorial system which was established by President Wilson in 1905. This system superseded the old one of lectures and recitations, still in use in most institutions. In some instances lectures and recitations were continued much on the old plan, with an addition of preceptorial work, while in other instances the bulk of the work became preceptorial. Preceptorial work as actually performed varies considerably in different departments. In the languages and subjects which place emphasis on reading, such as history, economics and philosophy, classes meet twice a week for lectures. They also meet once a week in small groups with the preceptor for the purpose of intimate discussion and report on assigned reading. In other subjects, particularly mathematics, preceptorial work is rather an additional aid and stimulus to weaker students. Preceptors have their appointed hours for attendance in the class-room and there they meet individual students who have been requested to appear because of evident weakness, or who come voluntarily for additional explanations and practice. By these meetings it was sought to bring about a closer intimacy between the student and his work, and between the student and his teacher. The preceptor should become the student's "guide, philosopher and friend" and thus stimulate enthusiasm for scholarship and learning, and devotion to the higher ideals of life, and also he should encourage him to form the habit of reading.

Much importance is attached to the method of the system,

not only because it brings about a closer contact of students and teachers, but also because it permits the work to be adjusted to the needs and peculiarities of the individual student. In other words, the preceptorial system is important on account of its flexibility. Nevertheless, it is evident that the merit of the system depends largely on the merit of the preceptors chosen to carry it out, and as this fact was recognized from the first, great pains have always been taken to insure obtaining desirable persons. In practice the plan has been sufficiently successful to warrant its continuance with only slight modifications.

The objections to the system are the enormous expense and comparatively small opportunity for promotion of preceptors, and the difficulty of obtaining satisfactory preceptors.

The Preceptorial Principle as Applied at Union.

At Princeton, technical education was scarcely involved, at least at first, the new scheme, and if it had been it is doubtful if the engineers would have been called on to play an important rôle in its development. It is safe to say that the preceptorial system has never received much attention from engineering teachers. At the present time, and always, it reflects its academic environment. Efficiency, in the engineering sense as ratio of output to cost, is not considered. Rather, at Princeton, they are willing to pay the price in order to get an output of the highest grade. The plan and conduct of the electrical engineering course at Union College is suggestive of the adaptation of the preceptorial system to engineering education. It might almost be said to be an embodiment of the engineer's idea of the way to carry it out. Yet, in laying out the course at Union, the Princeton system was not at all in mind, and consequently, the Union system is a quite distinct and original attempt to obtain for electrical engineering the ends sought by Princeton for her academic departments.

With a background of technical training in Sweden, and

with many years of practical engineering experience in this country, Dr. Ernst J. Berg took with him to Illinois a fresh conception of the way to meet the needs of electrical engineering students. At Illinois, he applied and developed his ideas, and coming back to Union, he brought with him the matured system which is now the basis of the electrical engineering course. In this course it is sought to turn out a product of the highest grade, but to do it with the utmost efficiency. The quality of the product is measured by the engineering knowledge, insight, power of analysis, power of concentration, discriminating sense, judgment, honesty, tolerance and enthusiasm of all those who graduate. It is believed that the course now offered at Union tends to develop all these qualities, but to do it with maximum efficiency.

Efficiency is obtained by the elimination of unnecessary administration requirements, of unnecessary duplication of lectures, of unfamiliarity on the part of one instructor with what another is doing, of unnecessary drilling and "forcible feeding" of students, and by the harmonious interrelation of students and instructors who live and work together every day.

The plan of the purely electrical work is extremely simple. It lays principal stress on a course of "theory" three hours a week, and a course of "laboratory" two afternoons a week, through junior and senior years. There are no other electrical courses given to juniors. Seniors spend three hours per week for two terms carrying out practical problems on "design," and one period of two hours per week through the year in a course called "Seminar" which includes presentation of papers and discussions by the students themselves. Some seniors also present theses, while others repeat in part, the junior theory.

The total schedule of both juniors and seniors is given as 17 hours per week. Approximately 70 per cent. of this time is given to engineering subjects of which 75 to 80 per cent. are electrical.

Details of the Courses.

The "theory" courses are conducted as follows: Dr. Berg gives the advance lectures, averaging slightly less than one a week each to juniors and seniors. The "theory" periods between lectures are given over to class work; recitations, quizzes and tests. For the class work the students are divided into sections averaging eleven men, each section under the direction of one of the instructors. This enables work to be done at the board, or in any manner that the situation calls for at the time. The principal problems are assigned at the lectures, and they are made to illustrate the subject under discussion. As no regular text-books are used, it is necessary for the student to avail himself of what is offered in class in order to be able to work the problems. He must draw heavily on his notes and his class-room practice, and, further than this on his instructors, for help. But he must do the work.

To give a specific illustration of the operation of the course we may take, for instance, the study of the short-circuit of alternators. This subject was reached as a natural development of the study of alternators, about the middle of February, and occupied the attention of the seniors for about two weeks. In the first lecture the fundamental equations of the transient armature current were derived, and the general conditions established, and a problem was assigned based on known experimental data. The problem called for the plotting of armature current from the short-circuit. As the result would vary, depending upon the particular instant at which the short-circuit occurred, the class was divided into groups, each group being assigned a different time of closing the switch. The physical idea of the transient phenomena was not easily grasped at this point, although the mathematics were entirely familiar, and it took several class hours of effort before it was felt to be time for another lecture. The second lecture was given nine days after the first, and consisted of a further development of the subject, in the establishment of the equations of other variables, that is, of the field

voltage and current, armature reaction, both for three-phase and single-phase short-circuit, and the power for single-phase and three-phase. This lecture was, in reality, not concluded until a week later. In the meantime the work of calculating and plotting was carried on, while the class work of assimilation continued on intermediate days. During this time the interest in short-circuits became so great that the class wanted to study them first-hand with the oscillograph, and consequently this became the order of the laboratory work. Incidently some peculiarities were discovered in the behavior of certain laboratory alternators, and of course these added to the interest.

At the same time in design, the alternator was being studied from another point of view, so that during the whole period the class was being steeped in this subject.

This is just one example of the operation of the course. The class procedure on other occasions may be quite different, and may involve a discussion of the previous lecture, or may require a supplementary lecture by the instructors. Each instructor, while following the same general scheme, will naturally be independent in his way of carrying it out. All instructors attend the advance lectures of Dr. Berg, or will have attended them in a previous year. These lectures form the basis and set the pace for the entire electrical work. The important feature of it is that the pace is adjustable, for just as soon as the students are ready for more, they get it.

At the same time work in the laboratory is running along parallel to the lectures. Frequently interesting questions come up in a lecture, and these may be at once investigated as a regular part of the laboratory work. The same opportunity for flexibility is found in the laboratory as in the theory. If students get hold of an interesting question they are encouraged to continue it until they have finished all that can readily be done. There is always an instructor freshly acquainted with the subject to suggest new lines of investigation. Furthermore, there are always two instructors present

at every laboratory period, whose services are always available but not obtruded upon the students.

The interrelation of theory and laboratory is made even more complete by short supplementary lectures given at the beginning of laboratory periods, intended to apply the theory to laboratory methods and vice-versa.

So much applies to both juniors and seniors. The latter concentrate their efforts even more closely on the subject in hand. While they are studying the induction motor in theory and laboratory, they are also working on induction motor design, and as a fitting conclusion of the subject, a debate is held in seminar on the subject "Resolved: that in general, squirrel cage induction motors are inferior to other types." It is easy to see that with such an attack on any subject, every man in the class feels himself able to talk intelligently and definitely upon it. Thus, the student has had the way constantly pointed out to him, but he has not been carried along. He has progressed by his own effort, he feels personally acquainted with induction motors and he likes them.

Faculty and Students.

The housing of the department is another very important element in the scheme. While the laboratory building was not designed to be used as at present, yet it has been possible, by careful planning, so to alter the interior as to provide two large recitation rooms and four offices, also space for students to work at large tables, all in addition to the regular laboratory. All engineering classes, both junior and senior, are held in the building. The actual time spent by students in the building will average over three and one half hours per day, per student. When it is considered that the faculty is practically always present in the building during the working hours of the day, and that their offices are always open, and accessible, some idea will be obtained of the relations between faculty and students. One junior, who was rather lazy, said that he would do the work all right if the in-

structors would just keep after him. But that is not a part of the system. There is no compulsion about the work except a moral compulsion, which comes to a student from his own knowledge that he must come up to the standard of the department or be dropped. This junior was told that he would be helped as much as possible but would not be driven. The natural result was that since then he has kept up by his own effort, and has learned a good lesson in self-reliance.

The work of the faculty is quite different in character from what it was under the old system. Class work is very light; it amounts to but five or six hours per week per instructor. From its nature it demands very little effort on his part. At the same time, much more effort is put into the work of going over the problems so that the student shall have the benefit of personal supervision of his work and may profit by having his mistakes pointed out to him. But, even this does not take a great amount of time, for the student has been taught and is required to do his work in an orderly manner.

In addition to prescribed teaching, every instructor is expected to be engaged in some scientific or engineering investigation. Since nearly the whole time of the faculty is spent in the laboratory under favorable working conditions, research becomes a natural occupation. Research, in so far as it involves experimental work, is conducted right in the laboratory where the students are also at work. The idea is to bring into touch all classes of work and workers, so that those just beginning may catch the spirit of those who have had a great deal of experience. Thus instructors, graduate students, seniors and juinors are all working more or less together. As more room is required, the work is simply spread out, but not to any great extent subdivided into departments. Incidentally, this has an advantage in the economical use of apparatus.

Relation of the Electrical Department to the College.

It would not be right to conclude without mentioning certain elements which belong to the college as a whole, but which

have a decided influence in the carrying out of the present plan at Union. Most important is the fact that the honor system in examinations is in force, and through its working there is no trouble in securing trustworthy results. Again, Union College is small enough so that students of all departments are well mixed and partake of one another's interests, and large enough so that an atmosphere favorable to any particular line of work may readily be maintained.

As evidence of the success of the system many incidents might be related which would all show a very unusual degree of enthusiasm on the part of both students and faculty. Of twenty-three seniors, it may be said that six expect to return for graduate work in full residence. An especially gratifying result is that the enthusiasm is not confined to a particular group of students, as for instance, the brightest ones, but every man feels with satisfaction that he has accomplished something which has been worth while, and that it has been by his own hard work.

Conclusion.

Princeton has devoted a large part of her resources to the maintenance of a system designed to bring students into more intimate relationship with learning and culture. The keynotes of this system are close association of students with preceptors, and flexibility of method. This close association calls for a great increase in the faculty, and flexibility is made possible by the increase. Flexibility is the most vital element in the method. Without it, close association would be intolerable. It is inseparably joined with the interest and progress of the individual student.

The weakness of the old method is in its inflexibility. It is a social order applied, without means of adjustment, to the individual. The rate of progress is the same for all, and fits only a few. Union College has accomplished flexibility in the electrical engineering department, not by an increase in faculty, but by a simplification and rationalization of its methods. Flexibility is the result of the method. To bring

about this change involved a recognition, first, of the futility of multiplication of courses; second, of the necessity and sufficiency of a sure understanding of the fundamentals on the part of each student, and third, of the essential elements of successful teaching. From this standpoint it was easy to arrange the present course. Electrical engineering may be peculiarly adapted to it in that, while there are many branches to the subject, they all radiate from the same central stalk.

In applying the principles of the system to another subject, or to another institution, considerable variation in details might naturally result.

At Union, account was taken of local conditions, and, fortunately, these all seemed to be favorable. Whether generally applicable or not, the results already achieved at Union have not only amply justified the course, but they have seemed to justify, as well, the preparation of this paper.

GRADING OF STUDENTS BY UNIVERSITIES VS. GRADING OF TECHNICAL GRADUATES BY EMPLOYERS.

BY C. FRANCIS HARDING,

Professor of Electrical Engineering, Purdue University.

The majority of employers of technical graduates select technically trained employees upon the basis of qualities quite apart from those given prominence in university grading and credits. The majority of universities do not study sufficiently the qualifications of their graduates most desired by the employers of technical men nor do they give sufficient weight to the grading of such qualifications. These two statements represent the premises upon which the following discussion is based and, whereas they are believed to be true after a considerable study of the subject by the writer, it is recognized that their truth will not be immediately granted by the average university reader. If some evidence or suggestion may be presented which will tend to confirm these premises or possibly only to arouse the interest of other instructors in the further study of this problem it will be felt that the purpose of this paper has been fulfilled.

Efficiency in the Educational Process.

Efficiency is defined as the ratio of output to input. In the all-absorbing struggle for increased efficiency in machines, labor and employees, increased efficiency is brought about in some cases by the decrease of input for a constant output or by an increase of output for a constant input. In some cases the question of the quality, commercial value or earning capacity of the output is quite as important a consideration in determining high efficiency as the output and input themselves. No university is wide awake nor can it keep pace with manufacturing or public utility corporations of the present

day that absorb its graduates if it does not make a careful study not only of the efficiency of the organization but of the possible increase in efficiency of its product. Failures to produce the highest efficiency are often charged by university faculties to too large an input for the equipment and financial resources of the institution, or more often to a grade of input too low, due to weaknesses in preparatory schools. All will agree that the amount and quality of the input cannot be governed at will by entrance requirements and it is the belief of the writer that more attention and study might well be given to the quality of the output measured in terms of requirements under which the output is to be used rather than to pay too much attention to the input or to lay the blame upon poor preparation of the raw material over which but very limited control can be exercised. This statement must not be interpreted as an excuse for low entrance requirements but rather an appeal for a continued study of the problem of the possibilities of higher efficiency in connection with the available raw material.

Student Personality Records.

Whether or not the faculty of a university believes that the requirements of the average employer are more exacting than they should be, or that it is possible to instruct the student along all the lines and develop in him the qualities desired by such employers, it will be recognized by all that if the judgment of the employer, which is sometimes based solely upon a short interview with the student, can be augmented by a recommendation from the department from which the student is to graduate, the chances of error in placing the student in the wrong line of work or of his failure in whatever line of work he selects will be greatly lessened. Recognizing this fact, it has been the custom for many years at Purdue University to obtain a majority vote of all the instructors in a given school expressing personal opinion regarding qualities of students, aside from scholarship, which

are recognized to be of most importance in practically all lines of work which the student may enter after graduation. The qualities selected are these: habits, mental caliber, speed, popularity, self-reliance, accuracy, address, industry, and reliability. There are, of course, many other qualities which might well have been included in this list but it is believed that it is sufficiently comprehensive to enable a fair estimate of the student to be obtained and is not so long and detailed as to prove burdensome. These records, taken at graduation, have been used both for comparison with the impressions obtained by employers during their rather short interviews with the students and also as a basis for recommendation for many years after graduation.

A Recent Experiment in Personality Grading.

The success of the above rather incomplete method, together with the belief that the university should make more of an effort to study the weaknesses of its students and attempt to improve them, have led to a recent experiment in the school of electrical engineering as follows: A record was made twice during the senior year in a manner similar to that outlined above, the first being taken in the first semester as soon as the instructors felt sufficiently well acquainted with the seniors to make a reliable estimate of their personal qualities. These records were then discussed with such students as were interested enough to make an appointment with the head of the department for personal interviews. In such conferences an attempt was made not only to impress upon the student the desirability of studying and improving his weaknesses but also to correct from further information gained from him any errors which are made by the instructors. With this information at hand a second estimate was made late in the second semester.

One modification of the above method has seemed desirable. Whereas the department records include a grade or a question mark for habits, depending respectively upon a definite knowl-

edge of good or bad habits or a feeling that the habits may be questionable, great care has been taken to discuss this matter with other students only when definite knowledge of the habits of the student under study is at hand. Little good can be done in discussing habits in cases where they may have been questioned largely upon an intuitive feeling rather than actual facts. Some change in our procedure should therefore be made to cover this point.

Some Results of the Grading.

When the new method was adopted a healthy interest was immediately aroused in the seniors and the study of their personal qualities was in general taken in the light in which it was presented even when the judgment of the instructors established a lower grade than was considered correct by the student in question. In the personal interviews the students were asked to state frankly what grades they considered to be in error and in most cases where changes were suggested there was considerable justification either for reconsideration of the grade immediately, or for a further careful study of the student with regard to the debated quality during the months preceding the next grading period. An unexpectedly large number of the class expressed themselves as anxious to learn of the impressions made upon the faculty and every student interviewed left the conference with at last an expressed determination to raise some or all of the grades before the next grade was to be established. It is interesting to note also that such a determination was often made by students who ordinarily have expressed little inclination to raise their scholarship grades above the value just sufficient to give them credit for the course.

Another interesting development of this method of grading was the request from the students that the class be graded independently by a representative student committee selected by the students themselves. The committee selected was made up of some of the most experienced and thoughtful men in the

class. Surprising as it may seem, however, their estimates were almost invariably below those of the department.

TABLE I.

Grading of Personality Characteristics.

First Column, Department Estimate; Second, Student Estimate.

Student No.	Mental Caliber.	Speed.	Popularity.	Self Reliance.	Accuracy.	Address.	Industry.	Reliability.
1	BC	BC	BB	BC	AC	AC	AC	AC
2	AA	AB	AB	AA	BB	AB	AA	AB
3	AA	BA	BB	AA	AA	BB	AA	AA
4	BB	BB−	BB−	BB	BB	BC	AB	AB
5	AB	AB	BC	AB	AA	BC	AA	AB
			etc.					

TABLE II.

Summary of Personality Grades in Per Cent.

	1914 Class.						Average 7 Years.		
	A		B		C		A	B	C
	Dept.	Student.	Dept.	Student.	Dept.	Student.			
Habits.....	79		20		1		88.5	9.2	2.3
Mental caliber..	40	32	53	66	7	2	39.4	53.7	6.9
Speed.....	28	11	65	76	7	13	31.7	58.4	9.9
Popularity	26	6	74	68	0	26	33.7	62.6	3.7
Self reliance....	54	28	40	66	6	6	56.3	36.4	7.3
Accuracy	35	19	63	71	2	10	41.7	50.9	7.4
Address.....	32	16	62	63	6	21	34.0	57.4	8.6
Industry.....	54	11	35	65	11	24	53.0	37.6	9.4
Reliability	71	21	29	65	0	14	72.6	23.9	3.5

Tables I and II give these results in detail. A study of the double columns of Table I, each line of which refers by number to an individual student, will indicate the differences between student committee and departmental estimates. In all tables "A" indicates merely "above the average of the class," "B" is "average" and "C" is "below the average."

In Table II a comparison of the percentages of the three grades in the entire senior class is made, showing more forcibly the very much smaller number of "A" grades and correspondingly higher number of "B" and "C" grades in the

student estimate. The last three columns indicate that the percentages of "A's" over seven years of study are not materially different from those for the 1914 class although the personnel of the department has materially changed in the meantime. This fact, together with the method of majority vote used to determine the departmental estimate tends to eliminate any bias due to partiality or lack of judgment from a practical viewpoint which might have affected the decision of any individual instructor.

Disadvantages of the Purdue Method.

Thus far no serious disadvantages have been found with this system and the only objections which might arise as to its use are, I believe, the following.

In some cases with students of particularly sensitive dispositions the fact that the judgment of the instructional corps does not rank them as high as they would expect or that this judgment is actually in error might create a feeling of resentment which could not be completely eradicated by the personal conference. Whether such a feeling would ultimately result in an improvement in the character of the student or otherwise depends largely upon the nature of the student himself. The few cases of this type thus far encountered have apparently developed a determination to improve the impression made at the time the first grades were determined upon.

The fact that in a class of seventy seniors in electrical engineering it is impossible for the majority of the instructors to be sufficiently well acquainted with all of the students to determine definitely upon their habits, prevents the greatest possible amount of good being done by this method. This fact, however, offers no reasonable excuse for failing to attempt as much as is found possible and usually the cases most deserving of personal attention are those in which the facts are quite forcibly impressed upon the minds of the instructors by the actions of the students.

One condition which was not anticipated and which upon

first sight would be recognized as a disadvantage to this system was that the majority of the students immediately compared notes among themselves with regard to their grades. In some cases this unexpected procedure led some individual students to believe that the knowledge of the instructors was superficial or prejudiced. In most cases, however, it resulted either in a second conference upon the initiative of the individual student whose grade appeared low, often accompanied by a friend who interceded for him; or a determination to convince the instructors at the next grading period that they were in error in their estimates. Both of these results seem to work out as advantages of the method rather than otherwise.

Possible Objections to the Method.

It will immediately be argued by those engaged in university work where the classes are large that the time required for such an investigation as that described is too great. The only answer to this argument is that no time can be more efficiently used by any instructor in any university than that which he spends in determining and attempting to improve the personal qualities of the students with whom he comes in contact. If he is engaged in instructional work for purely altruistic motives and is to become a successful instructor, his ambition to improve the quality of the output of the university and to increase the efficiency of its graduates not merely from a scholarship standpoint but also in all the qualities herein set forth is not only most commendable but well worthy of considerable extra time.

Summary and Conclusions.

The advantages of this system, aside from those which have been incidentally set forth above, may be briefly stated as follows:

It suggests to the students, often for the first time, the qualifications aside from scholarship, which are of prime importance for their own training and welfare and upon which they are

judged by those to whom they are to apply for employment in the future.

It arouses in the students an interest in correcting their weaknesses in these various qualities and their interest along these lines seems to exceed, on the average, that expressed in obtaining high scholarship grades.

It corrects errors in judgment of the student by the instructor and assists the student who may have inherent good qualities but who, for some minor reason, is unable to make such qualities recognized by those with whom he comes in contact.

It offers the best possible opportunity for personal conference between students and instructors and particularly with the head of the department, who makes it a point to discuss these matters in detail with each student who expresses a desire to do so.

It broadens the judgment of the younger and less experienced instructors and permits them, sometimes for the first time, to judge students from the same viewpoint taken by employers. Too often instructors, particularly those in academic departments or those who have not had actual experience in practice, make the mistake of judging students purely from the standpoint of scholarship.

It offers a much fairer basis for recommendation of students not only to employers with whom they are to come in contact during the senior year but also for positions in later years. The records are obviously fairly accurate after having been taken twice in the senior year, especially when such records are discussed with the respective students.

Further, it is hoped that this method will be of great assistance to employers, since the writer knows from experience that the employer dislikes to offer a position to a student entirely upon the basis of a comparatively short personal interview and he further hesitates to give very much weight to the recommendation of the instructor since this is too often based to great extent upon a scholarship record.

In conclusion the results are such as stated and the predic-

tions which the writer ventures to express in writing for the first time may be interpreted as the hallucinations of a dreamer. He firmly believes, however, that out of the present rather serious, and to a large extent justified, criticisms of the employers of technical graduates which have been showered upon the universities in the last decade will come an awakening of the university to the fact that it is not so large and unsympathetic that it cannot in the future take rather radical steps to improve the standard of its graduates. It will thereby increase their possibilities for success when turned out of its gates into a world which demands for success in practically every profession not only the best scholastic preparation but also the best possible standing in personal qualities. If in the future this study can be carried into all four years of the university life of the student and if one person, preëminently qualified for such work, can be appointed upon the university staff to make such studies of all students and to suggest to the students themeselves or to the instructors possible improvements in the qualities of the individual or the class as a whole, it would result in one of the most important efficiency campaigns yet inaugurated. If the large manufacturing and public utility corporations would also establish a department or employ an individual to make the same careful studies of their employees that they make of their raw material and their product in process of construction, and would coöperate as far as the technical employees are concerned with the universities furnishing such employees, and if they would feel frank to criticize in sufficient detail the training and qualifications of graduates supplied to them by the university it is believed that not only the efficiency of the university and the corporation per se might be improved but the combined efficiency of both working as a unit would be greatly augmented and each would appreciate better the difficulties under which the other is working.

BETTER ENGINEERING TEXT-BOOKS.

BY F. H. SIBLEY,

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The critics of engineering education have generally directed their criticism at incorrect methods and incompetent teachers, while poorly written and illy adapted text-books have been ignored as a factor in the so-called failure of technical-school training.

If the relatively great amount of time which students are expected to spend in the study of books is to be profitably spent the books should be so written and arranged as to demand the minimum of time and effort in the reading. That the maximum of time and effort is demanded is apt to be the case.

Good books are harder to find than competent engineers or successful teachers because the literature of the profession has lagged behind professional attainment. The reason for this may be found in the fact that successful practitioners are not always trained for writing books and the quality, if not the quantity, of the books that have been written indicates that success in one line does not necessarily mean success in the other. Then too, technical writing has been regarded much as a "yellow dog," and since it seldom pays either in money or reputation the engineer who is competent to write a book must do it as a matter of professional interest or duty.

Some Text-Book Faults.

There are certain faults in the books that are so glaringly evident that one need not be a literary critic to point them out. Prominent among these is the misuse of symbols and formulas. In books that contain mathematical demonstrations it is not uncommon to find ideas stated symbolically when plain English would have answered the purpose better.

When the same symbol is used to represent more than one thing or its meaning not stated in close proximity to where it is used, exasperation is added to the other troubles of the reader. The labor of reading and comparing several texts would be greatly diminished if there could be some recognized standard for the meaning of symbols.

In the derivation of formulas gaps are frequently left between one form of an equation and another without any explanation of the intermediate steps. Here is an example:

An expression for the derivative dp/dt is obtained by differentiating the equation,

$$\text{Log } P = \log k - n \log \frac{T}{T - b}.$$

Thus,

$$\frac{dp}{dt} = np\left(\frac{1}{T - b} - \frac{1}{T}\right) = \frac{nbp}{T(T - b)}.$$

Such condensed mathematical processes are out of place in a text-book where instead of being an aid to the understanding of the subject, they are a hindrance.

Another fault results from carelessness in the use of certain classes of words. Among these are common English words like those mentioned in President Alderson's articles in the BULLETIN of February and March, 1913, entitled "Miscellaneous Faulty Expressions." This list might profitably be extended by publishing the complete compilation which the author mentions in the footnote.

Familiar words used in an unfamiliar sense and unfamiliar technical words are two other classes that are likely to give trouble to the student. The dictionary will not always help even with the first-named class and as to the second, almost every species of animal and household appliance has a technical counterpart that the dictionaries do not mention at all. What is true of standardizing symbols applies with equal force to the advantage of standardizing words of these two classes and this work can be undertaken none too soon.

The use of the words "former" and "latter" should also

be mentioned as examples in this connection. These are handy expressions when properly used but when they are separated by several sentences from their antecedents, they add enormously to the labor of the reader.

A third fault is that of giving so much detail either in the form of unnecessary words, phases or material that the reader is bewildered and loses sight of the fundamental ideas. The following example is a good illustration of the "long-winded" style that results from using too many words:

"The total ratio being settled on, and that allowable, as a maximum, for the single cylinder, it becomes easy to determine the best number of cylinders in series. The first mentioned ratio is that of maximum commercial efficiency, as just stated; but the second must be taken as that which gives the highest efficiency of engine, the back pressure in that cylinder and its friction, taken singly, being considered, together with its proper proportion of the friction of the engine as a whole."

The technical student ought to be, and generally is, too busy to waste time in sifting such abstruse paragraphs as this. Some pretend to think that such reading furnishes good training of the perceptive faculty but if the student gets any training at all from it, it is likely to be at the expense of his moral character and besides it is better to acquire mental training by *mastering* principles rather than by *digging them out* from a mass of obscure English.

Equally annoying to the reader are such hackneyed and foolish expressions as "It is evident," "As everybody knows," "It therefore follows." These statements are apt to precede, humorously enough, a wordy explanation of the evident thing which everybody knows, or is supposed to know.

Unnecessary material in the form of historical, reminiscent and amplifying paragraphs would nearly always be better left out. For example, how many books on the subject of heat engines begin with a description and illustration of Hero's engine? This is useless "lumber" and nearly always fills the place of something the book should but does not contain.

Perhaps the worst fault of all, as well as the most common, is that of poor arrangement. Poor in the handling of detail and poor in the sequence of chapters or divisions of the subject.

In the matter of detail, the confusion of ideas that results from a bad arrangement of sentences and paragraphs is familiar to most readers. In this respect many of the books are little more than a heterogeneous collection of facts wherein not only are the principles, which the author is trying to set forth, obscured but the facts themselves are made unavailable. Who has not turned over and over the pages of some well-known book in search of information that ought to be in a certain place and found it at last tucked away in an obscure sentence of an unimportant-looking paragraph?

Careless chapter planning results in illogical treatment of the subject, which is impossible for a class to follow. That this is not an imaginary failing is shown by the following illustration taken from "The Steam Engine."

TABLE OF CONTENTS.

I.	Introduction.
II.	Commonest Form of the Steam Engine. (Includes a discussion of the Gas Engine and the Steam Turbine.)
III.	Value of Expansion.
IV.	The Indicator.
V.	The Reciprocating Motion.
VI.	How the Valve Acts.
VII.	Valve Gears.
VIII.	The Exhaust and Feed.
IX.	Flywheel and Governor.
X to XIV.	*Steam Boilers.*
XV to XVII.	Thermodynamics.
XVIII.	Properties of Steam.
XIX.	Properties of Gaseous Fluids.
XX.	Entropy.
XXI.	Water, Steam, ϕ Diagram.
XXII.	Cylinder Condensation.
XXIII.	*Combustion and Fuel.*
XXIV.	*Boiler Efficiency.*
XXV.	*Gas and Oil Engines.*
XXVI.	Valve Motions.

XXVII.	Inertia of the Moving Parts.
XXVIII.	Kinetic Theory of Gases.
XXIX.	Thermodynamics.
XXX.	Superheated Steam.
XXXI.	How Fluids Give Up Heat and Momentum.
XXXII.	*Jets of Fluid.*
XXXIII.	Cylinder Condensation.

The faults indicated, as well as many others that might be mentioned, all contribute to a literary style that results in the student acquiring incomplete and erroneous notions, slipshod methods of reading and repugnance to all study of books.

How Books Might be Improved.

That a good literary style is possible in dealing with even the most technical subject was well illustrated in a recent issue of one of the non-technical magazines. It contained an article by an experienced writer, on the Diesel motor. Only one or two short paragraphs were given to the description of the motor itself yet it was handled in such a way that even a non-technical reader could not fail to understand the principle of the machine and how it differed from the automobile engine with which it was contrasted. Not only this but the article was delightful reading. A description covering the same ground, in the ragged, obscure and jumbled up style of some of the engineering text-books, would have filled pages, made the driest of reading and would have been unintelligible to any but the initiated.

Aside from literary considerations there are certain practical aspects in which both the appearance and usefulness of the books might be improved. Among these is a complete cross index. Scarcely two people will look up a subject in the same way and unless the index is carefully planned the book is of little use as a reference.

Lettered sketches should be kept close to the text which refers to them. The interruption caused by turning back or forward to a reference sketch is burdensome, especially where the same letter in the capital and lower case form is used.

Sketches should be simple; they should contain all of the lines and symbols referred to in the text but no more. This seems almost too self-evident to need mention, yet it is astonishing how often it is unheeded.

The appearance and convenience of books would be improved if all publishers would follow the example already set by some and adopt one or two standard sizes instead of the half dozen sizes that are now common. There seems to be no good reason why there should be more than two, the pocket-book and the six-by-nine sizes.

While undoubtedly books have been improved very much in the last few years it is pertinent to ask what, if anything, can be done to accelerate the process. To point out the faults is easier than to suggest a feasible remedy. It is not probable that there is any panacea, books will continue to improve gradually in the future as they have in the past but those who recognize the need of improvement will probably admit the truth of the following general propositions:

Writers should be trained for this particular work, they should do research work in sifting and compiling available material and arranging it with the student's point-of-view always in mind and with an intimate knowledge of his needs.

More constructive criticism is needed of books before they are published. The detail plans of any important engineering structure are checked and re-checked and a text-book is a sufficiently important work to demand the same treatment. No writer, however wise he may be, is likely to produce a very good book without the help of such criticism, and any author, especially a young one, who takes the position with the publisher that his book must be printed as written or not at all, is foolish to say the least.

Books should bring better compensation to authors and publishers, something which would take place automatically with increased sales. Increased sales would also result in better later editions and decreased cost to the purchaser. Paying several times what a book is worth is a real burden to many students and one which should be eliminated.

A Comprehensive Text-Book Committee Needed.

The question now arises, What can be done to bring about these results? As one suggestion, a joint text-book committee might be appointed by the engineering societies and the publishing houses whose duty it would be to aid and encourage the production of better books. While to specify the duties of such a committee beforehand would not be easy, the following suggestions would seem to be practical and if the committee were once organized, its activities would undoubtedly be broadened and better defined.

It could support the publishers in many cases in insisting upon rigid criticism by competent authority, before the publication of a book. It could not, of course, take under consideration all of the great number of books that are offered nor would it need to do so but only those that had been accepted for publication.

The members of the committee might encourage writers of promise or of proved ability by using their influence with college authorities to have other duties made lighter so as to give more time for writing.

The committee might publish an authoritative book review and perhaps recommend certain books for certain courses. This recommendation would be an aid to teachers in selecting a text and presumably it would encourage broader use of the best ones and discourage unnecessary duplication.

It could help to carry on the work, already started, of standardizing words and perhaps do something towards standardizing symbols. It might also consider the matter of uniform sizes of books.

To carry out all or any one of these suggestions in detail would be no small task and perhaps no committee could be expected to do gratuitously all of the great amount of work indicated, but the simple fact of the existence of a committee known to be working for the improvement of the books, would of itself be a tremendous force in this direction.

A REPORT OF PROGRESS IN COÖPERATIVE EDUCATION.

BY A. M. WILSON,

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About twelve years ago, very few educators had even heard of what is now called coöperative education. They may have run across some casual mention of the principle involved, by ancient or mediaeval writers on the subject. But as none of these statements was the result of a carefully devised plan to meet an apparent need of the civilization of the time; they evidently failed to produce any result.

When Herman Schneider worked out the plans for what he has called the coöperative system of education, and presented them for the consideration of several manufacturers, as a means for developing the trained men they needed, many of those who had occasion to consider them were strongly impressed. The advantages of the scheme were obvious. But it was such a radical departure from educational practice, that no manufacturer could be prevailed upon to give it a trial. While the ordinary form of technical education was of comparatively recent development, it seemed to be hoary with tradition when compared with Schneider's proposition that students should learn the practice of any trade or science by practicing it. And it is possible that teachers were not enthusiastic in recommending or approving a system of education which obviously involved more effort on their part.

Even now, there are those who do not appreciate what this new departure in education means. It is not the province of this article to go into a discussion of the ideals from which the practical ideas of the coöperative system developed. Possibly there is no better way to arouse interest in it, than to tell what has been accomplished in one field only. For the ideals themselves include possibilities which would probably

seem, to the conservative mind, as far beyond the present achievement, as it is beyond the older educational methods.

Early Problems of Coöperative Instruction.

Possibly the most striking thing about the coöperative system as applied to engineering education, and as it may be applied in any other field of human endeavor, is that it is a business proposition which appeals to the manufacturer or operator who needs trained men. It will not do to infer that all manufacturers and operators clamor for it the instant it is presented to them superficially. Sometimes it seems that the art of persuasive speech has to be developed to a very high degree, to secure the consent of some business men to a proposition which cannot fail to benefit them directly. But it was realized from the first, that the success of such a system would have to depend entirely upon its ability to meet commercial conditions at least as well as any other educational system. As in all new developments, there were many details to be changed, to meet unforeseen emergencies and changing conditions. For instance, when the course was started, the students in the school and in the shops alternated weekly; that is, one student would be at work for a week while his alternate attended the university. Recently this alternation of school and shop has been put on a bi-weekly basis. And it is proposed to make a still more marked change to suit the conditions peculiar to the civil engineering course. But the coöperative system of education has lived for eight years. It has passed the purely formative or probationary period, and now stands upon a clearly outlined commercial basis, offering an opportunity for education which seems to meet the educational needs of the democracy.

In 1906, Dean Schneider, who was then teaching in the civil engineering department of the University of Cincinnati, was given an opportuntiy to try his scheme. In a way, the situation was favorable. Possibly it is interesting to note that he, a civil engineer, made the application to mechanical engi-

neering first. At that time there was almost no connection between the engineering departments of the university and the large and growing engineering interests of the community. So far as the university was concerned, very little could be lost by the failure of the scheme. And failure was freely predicted.

There was the usual inertia of ultra conservatism to be overcome, and there are many interesting stories, which might be told, of the difficulties which Schneider encountered. He had not only to persuade manufacturers to enter into coöperation with the university; but he had to persuade students to enter this new educational scheme. But the obvious economic advantages were sufficient to attract the necessary number of students to make a start.

The Appeal of Coöperative Training.

The appeal made to these first students has not been changed since. It contains the basic principle underlying the coöperative scheme of education. It merely states that, in a democracy, the only limit to educational advancement should be the lack of ability on the part of the student. It should be, as nearly as possible, independent of financial and social conditions. There should be no "royal road" in any sense. An ambitious mechanic, living in Cincinnati, who has a son sufficiently talented to acquire a college education, may, through the coöperative system, give him such an education without bearing a heavy financial burden. A student's earnings will be sufficient, right from the start, to pay all the necessary fees, buy all the necessary books and other equipment, and clothes, and to pay more and more towards the other living expenses as his value as a producer increases.

While the first appeal was most effective with those to whom the financial problem was a serious one, the educational advantages seem to be appealing more and more strongly to those to whom the financial problem is not so serious. It is interesting to note that a very large percentage of applica-

tions for entrance into the college comes from well-to-do youths who are anxious to put themselves to the test of actual service. It would seem that this in itself must be a decided advantage.

Eight Years' Growth.

For the first two or three years, the growth was not phenomenal. But the advantages both to the students and to the business interests employing them soon began to be appreciated, and the demand for enrollment in the engineering courses increased rapidly. During the years following the 1907 panic, when the enrollment in other engineering schools decreased to a marked extent, the attendance at the University of Cincinnati showed a healthy increase.

The enrollment in coöperative engineering for 1913–14 was practically 400. The limitations of facilities to properly care for more students permitted only one hundred and eighty freshmen to enter. There were more than three thousand inquiries. What might be called a practical test of the scheme was had during the business depression of last winter. At no time was the operation of the courses affected to an extent, although the work of those in charge of shop arrangements for the men was necessarily more difficult than usual. Even if the depression had been so severe as to necessitate the closing down of all the shops in the city, that would not have indicated a weakness in the coöperative principle. But time and space will not permit of a proper discussion of this phase of the question.

Incidental But Essential Educational Features.

It has been necessary, in operating the coöperative courses, to consider education from many new view points. One of the important matters demanding practical solution was the problem of getting the right man in the right job. This did not provide a field for the vocational guidance expert of the type which seems to have fallen into some disrepute recently. Dean Schneider has made an interesting attempt to put men

into work for which they are best suited. To do this effectively an extended series of observations has been carried on. Some of these observations have been made by instructors, some by shop foremen, and some by the department of psychology. When sufficient work has been done to warrant it, there should be material for a rather interesting paper along this line.

Another feature connected with the coöperative work is the analysis of the courses of study, to adapt them to the needs of the men. It is quite apparent that such a radical change in educational methods would necessarily involve considerable change in the arrangement of curricula. It may be stated, that we have just recently reached the point where no further change of a pronounced character is anticipated.

From the study of the curricula and the necessity for keeping records of the students in shop and school, the faculty room has developed into a sort of educational laboratory. From the fact that freshmen needed some sort of elementary instruction regarding their jobs, to work efficiently, a rather elaborate system of syllabi is being worked out, not only for the shop work, for the benefit of the students, but for the class work, largely for the benefit of the faculty. The study of object, method, matter and mechanism connected with the work of the students, suggested corresponding studies in connection with the various subjects of the curricula. These syllabi of class work will serve to systematize the pedagogical work of the faculty to a much greater extent than would be possible under the usual methods of more restricted discussion of such subjects.

Relative Cost of Coöperative Teaching.

As in the case of nearly every other new departure in the field of human endeavor, the claim is made by its sponsors, that not only is higher educational efficiency obtained, but that this is accomplished at lower cost to the community. It is understood that it is hard to estimate values in such work as education; but there should be limits to such concrete values

as the amount per student per year, which is not paid directly by the student.

If we confine ourselves to the intangible values, we are at once confronted with the fact that, in addition to actual experience in productive work, the coöperative student gets whatever value there may be in the technical and cultural studies offered at the University of Cincinnati, while he is in direct contact with the problems of capital and labor, and the conditions under which large numbers of men earn their living and live their lives. The fact that summer employment is encouraged by all technical schools indicates that these values are appreciated. But this summer employment is carried on usually in a hopelessly desultory fashion with no responsibility on the parts of either the faculties or the students. There should be more of this intangible value in such systematized practical experience as is offered in the coöperative courses, than can possibly exist under the usual lack of system.

Regarding the values as expressed directly in money cost, the time available for this article did not permit a careful scrunity of the financial statements of institutions, so that the various items involved in education might be properly charged. It is probably not far wrong to say, that it would be a very difficult task to apportion the cost of education properly among the various departments, even if the financial statements of many institutions were available. A superficial study of such data from about twenty-five institutions of higher learning indicates that the average cost per student per year, on the basis of gross income, varies from about $600 to about $170. This, of course, does not include any percentage of the investment in buildings, land and other necessary equipment which has cost money. The average of the above values of cost per student per year, by institutions, amounts to about $320, not including percentage of lands, buildings and equipment. To find the apparent average net cost per student per year, the proper amount should be added to cover the cost of land, buildings and equipment, and from the result should be subtracted the amounts paid by the student as tuition and other fees. It

might be stated that some of the institutions considered maintain both medical and engineering schools, and some do not. The gross cost per student seems to be independent of such conditions to quite a marked degree. In finding the average apparent net cost per student per year it will not be safe to take the values of tuitions and other fees given in many catalogues. In some colleges at least there seem to be so many reasons for remitting fees that a comparatively small number of students pay them. At the University of Cincinnati the average cost per student per year on the basis of gross income is about $170. The average apparent net cost per student per year, after the additions and subtractions mentioned above have been made, is about $135. In considering even this comparatively small amount, it should be borne in mind that the students return directly to the community which supports the university, through their living and other expenses, sufficient revenue to largely, if not entirely, offset this investment. This latter condition cannot be true in the case of those institutions whose funds come from a comparatively large territory.

Gains Made in Eight Years.

Another effect of the coöperative courses upon the engineering faculty is due to the necessity for a careful study of the manufacturing and operating conditions around Cincinnati. It has been necessary, in planning prospective courses, to look over the community, to see what opportunities there may be for practical coöperation. Doubtless, in the future, it will be necessary to secure accurate data along these lines. As a matter of fact, these data will probably be accumulated in the natural course of events.

During the past eight years, the number of students enrolled has increased from a dozen or so to 400. The number of coöperating concerns has increased from two or three to more than sixty, including the engineering department of the city of Cincinnati, two steam railroads, two electric railways, and a wide range of manufacturing and operating companies.

This broadening of the activities of the engineering college has in itself brought up problems in connection with the coöperating concerns which have involved additional time and labor on the part of the faculty. For instance, coöperating concerns are invited to use the facilities of the university to a reasonable extent, through their students. In this way, many interesting problems come up for solution which are of some value to the business interests of the community.

It may be of interest to note that the coöperative principle is being given more and more recognition of a very effective character. About twenty institutions of different types throughout the country have adopted this principle. So far as is known, all are meeting with success. Those in charge of such courses have to bear a little more responsibility than is involved in the older educational methods. But it does not take more than human intelligence to deal with other human beings in any business proposition. And all that is involved in the coöperative principle, is a combination of business and education in an attempt to approach more closely the ideal in education;—that every one capable of receiving an education may do so, regardless of his immediate financial and social condition; but that he be as little of a burden to the community as possible while receiving it.

A DEPARTMENT OF ENGINEERING IN THE JOHNS HOPKINS UNIVERSITY.

BY JOHN B. WHITEHEAD,

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The Johns Hopkins University has announced the opening of a department of engineering. This entrance of Johns Hopkins into a new field of activity has been made possible by an act of the General Assembly of the state of Maryland appropriating for the purpose a substantial sum of money for buildings and equipment and also a continuing annual income for maintenance. The laboratories are now in process of construction at Homewood, the site of the university's new home in the northern section of Baltimore, and the first undergraduate class is already in attendance.

This new move was, perhaps, received with surprise by many who are familiar with the history, aims, and past efforts of the university. The character of the educational training for the profession of engineering in this country has not generally been such as to suggest a legitimate field of effort for an institution which has limited itself almost entirely to strictly graduate or university activity. While a number of colleges and engineering schools offer graduate courses in engineering, in nearly every case these courses have been added to an undergraduate curriculum in engineering and they have not attracted many students. By far the greater number of students complete their formal professional training at the end of the undergraduate course. Harvard, for several years before the merging of its school of applied science with the Massachusetts Institute of Technology, exacted a baccalaureate degree for entrance, but in spite of its high purpose the plan did not result in marked success, and is now apparently abandoned in the coöperative merger with the Institute of Technology.

DEPARTMENT OF ENGINEERING IN JOHNS HOPKINS.

Since its inception and foundation The Johns Hopkins University has emphasized as its chief aims investigation, research and graduate training. The standing and reputation it early created for itself in this field of the pure university and which found concrete expression in its faculty of philosophy, have also been sustained in the plan and subsequent development of The Johns Hopkins University medical school. The questions may well be asked, therefore, why Johns Hopkins has undertaken work in a field which, at first sight, appears foreign to its traditions and tastes, and what influence these traditions will have upon the methods which will be adopted in its new work.

History of the Inception of the New Department.

The circumstances leading to the Act of the Legislature making possible the creation of the new department apparently began with a prospectus which was prepared about six years ago, when the university was making an appeal for financial aid in its plan to move to Homewood, the beautiful site presented by several of its friends in Baltimore. This prospectus announced several directions in which the university wished to extend its efforts after removal to its new home. A graduate school of applied science was mentioned as an especially promising field.

While the appeal for a school of applied science failed to make impression on the wealthy philanthropist, it nevertheless excited many public expressions of endorsement. It was suggested that the state of Maryland should provide means by which Johns Hopkins could create an advanced school of engineering which should offer special opportunities to the residents of Maryland. It was pointed out that inasmuch as the university had already a well-organized system of courses in the sciences and other branches preparatory to training in engineering, an excellent opportunity was open to the state to secure a school of engineering of the best type at moderate cost, if the university could be prevailed upon to undertake

the responsibility. The press kept the matter constantly before the public, and sought the opinions of many prominent men, publishing them from time to time. It appeared that there was a very large sentiment in favor of the project. Among other things, attention was called to the large number of manufactures in the state requiring technical skill, to the number of men of technical training employed by railroads, public service corporations and state activities, and also to the fact that there were more than three hundred residents of Maryland pursuing courses in engineering in schools and colleges outside the state. As a result of this activity shortly after the convening of the Legislature, a bill was introduced appointing a committee of legislators to confer with the university as to the feasibility of the plan and as to the willingness of the university to assume the obligation and responsibility.

Throughout this campaign the university remained in a neutral attitude. While a number of the alumni were enthusiastic advocates of the plan, there was at first within the institution some feeling that the assuming of such a responsibility as was proposed might in some way impair its ideals and possibly lessen its prestige. However, with the appointment of the committee of the Legislature and the later appearance of a possibility of success of the plan, all doubt as to the duty of the university was quickly removed in the minds of the trustees and faculty. The committee of the Legislature was invited by the university to visit a number of schools of engineering, the value of engineering education was pointed out, and estimates were made and submitted as to the amount of money necessary for buildings and equipment and for annual maintenance. Thanks to the discrimination and broad attitude of the committee a favorable report was made to the Legislature and a bill was introduced appropriating $600,000 for buildings and equipment together with a substantial annual sum for maintenance.

Too much cannot be said for the broadminded and intelligent consideration which was given to this bill while it

was before the Legislature. Naturally there was some opposition and many amendments were introduced which, had they been incorporated in the bill, would have deprived it of much of its value. As finally passed, however, it is doubtful whether a more liberal and far-sighted provision for university aid has ever been made by any state. Under the bill The Johns Hopkins University is absolutely free to conduct engineering education as it deems best. Its sole obligation is the awarding of certain scholarships carrying free tuition to the residents of various counties and legislative districts of Maryland. The legislative bill, in fact, exacts that its provisions shall in no way restrict the university in the standards which it sets for entrance, for conduct and for graduation. It stipulates that the standards to be maintained in the teaching of engineering shall be equal in all respects to those in other departments of the university. While not explicitly required and while the school is described as a school of advanced technology, it is nevertheless the obvious intent of the bill that the university shall provide courses of undergraduate instruction. In all other particulars the matter is left entirely to the university to adopt such methods as it sees fit, without scrutiny and without legislative or other suggestion. The passage of this bill is a signal tribute both to the character of the men comprising the Legislature of 1912, and also to the standing and confidence which The Johns Hopkins University enjoys in its own state.

Preliminary Survey of the Possibilities.

With the passage of the legislative bill an accomplished fact, the university authorities were confronted with a number of important questions which required answer before definite steps for creating the new department could be taken. What should be the general scope of the work to be undertaken? Should greater emphasis be given to undergraduate or to graduate instruction? Should the plan be patterned after that of existing schools of high standing or should modifications be made? What should be the relation of the new

department to the existing organization of the university? Should these questions be determined before or after the initial faculty was chosen? What steps should be taken in order to put the new buildings and laboratories under construction as promptly as possible?

The university was not, however, entirely unprepared to answer questions of this nature. A number of members of the scientific section of its faculty have long been in touch with those branches of engineering most closely related to their respective subjects. In particular the departments of physics, chemistry, and geology have been identified with a number of projects involving engineering skill. It will be remembered that the late Professor Rowland was a member of the international commission which reported upon the feasibility of the utilization of the power of Niagara Falls. Since that time the university has always maintained, as part of its department of physics, graduate courses in applied electricity. Ex-President Remsen has been an active member of the State Roads Commission of Maryland, and of the Sewerage Commission of Baltimore. The Department of Geology has been actively associated with the Geological Survey of the State of Maryland, and with the work of the State Roads Commission. Professor Clark is the State Geologist, other members of the department are on the scientific staff of the commission, and Professor Reid has rendered important services in the development of improvements in road construction. Other departments of the university have also participated in undertakings of similar nature outside the university.

During the visits of the legislative and university committees to the principal engineering schools of the east, and also through correspondence with the officers of these institutions, valuable definite knowledge had been gained as to the amount of money which would be needed to start a school of engineering having three or four departments, and the probable annual cost for operation. The information so gained was the basis for the amount appropriated in the bill for these purposes. Upon the passage of the bill a committee of the faculty began

a further systematic series of visits to existing schools of engineering This series of visits extended over several months and embraced practically every engineering school of importance east of the Mississippi River. Also during this time a number of prominent consulting engineers were invited to Baltimore and their opinions asked as to how the efforts of the university could best be directed in its aims to provide proper education for students intending to become engineers, to offer opportunity for advanced study, and to contribute to the advancement of knowledge in engineering and applied science. A number of presidents of manufacturing companies were also consulted in person and by correspondence as to their experience with graduates in engineering, and their ideas as to how the shortcomings of these graduates could best be corrected.

Faults of Engineering Courses in General.

It became evident very early in these visits and conferences that engineering education in this country is not on a satisfactory basis. All four of the national engineering societies have committees on engineering education, and the Society for the Promotion of Engineering Education has existed for a number of years. The literature which is produced by these bodies, and that by independent and generally complaining commentators, is replete with suggested modifications and plans for removing the existing imperfections.

It seems to be generally admitted that the present schools of engineering, with, in many cases most elaborate equipment, are failing to turn out graduates properly equipped to meet the needs of the manufacturing and other engineering organizations which they enter. The field now represented by any one of the particular branches of engineering, is so wide that the attempt to cover it in the usual undergraduate course has resulted in the continuous introduction of new subjects, the shortening of the time allotted to others and a tendency to sacrifice instruction in fundamental subjects in order to include the study of new applications in the respective branches of engineering. It is not unusual, for example, to find ten

subjects taught in a term of one half year, some of these being, therefore, limited to one hour of instruction per week. In these schools special engineering instruction begins either in the first or second year, and little or no attention is paid to the fundamental and general subjects thereafter. The usual result is that the average engineering graduate is wanting in general education, in powers of expression, in imagination and ability to reason. As possible offsets to these deficiencies, he has had a survey of numerous special engineering methods and applications, with many of which he may never afterwards come in contact, and has spent much time in courses in shop work, manual training and the testing of machinery and materials.

An excellent summary of the imperfections mentioned has been given by Professor C. H. Benjamin, dean of the engineering schools of Purdue University, who made an attempt to secure the subsequent history of 3,700 graduates in engineering. He sought particularly opinions as to their fitness for professional work and suggestions as to how educational training could be altered with promise of improvement. He received some form of statement in connection with 3,500 names. Among the replies were those of a number of employers of engineering graduates. Stated briefly the general conclusion from this investigation was that the graduate lacks practical experience, has little knowledge of commerce, business methods and economics, and must devote himself in some way to acquiring further information and knowledge of affairs for several years; that he will accomplish the above more readily if in college he has applied himself to fundamental sciences and avoided too great specialization; that the literary side of his education has been too much neglected; and that the graduate is frequently unable to express himself properly in either writing or speaking.

Among the educators, engineers, employers and others consulted by The Johns Hopkins University, there was general recognition of the imperfections which have been mentioned. Particularly widespread were the complaints of too great in-

sistence on professional training to the sacrifice of fundamental and cultural studies. The committee carrying out the study has repeatedly asked of educators why attempt has not already been made in the way of correction. There have been two answers: first, that by certain schools the only remedy is thought to lie in the institution of five or six-year courses, thus providing the additional time necessary for the pursuit of both the cultural and professional studies; and second, that in many cases there is enough inertia in the established curriculum and surrounding tradition to make difficult any radical change in an existing course.

There are manifest advantages in terminating an undergraduate course of instruction at the end of four years. This is an almost universal custom, whether in the college of arts and sciences, or in the school of engineering; and it offers a convenient point of separation into business life, profession, or more serious study. Certainly more ground can be covered in five and more still in six years. But are five years enough for both cultural and professional training? And if six, is it not more logical, to offer a baccalaureate degree at the end of four years followed by a professional degree after two more? This plan offers a convenient stopping point for those not qualified for further rigid professional study, and may nevertheless provide good preparation in the four years for many subordinate engineering positions. As regards the difficulty of changing established practice and tradition, there is obviously no reason why the curriculum of a new school should not be so shaped as to embody as many new features as seem advisable in the light of competent criticism of present methods.

General Considerations in an Engineering Course.

It is obvious from what has been said that there is increasing recognition that engineers must also be educated and cultured men and that the present engineering school needs to alter its methods in order to bring about this desired result. The best available remedy evidently lies in the adoption of as much

as possible of the usual college course in the arts or in science. In other words the results would be better if professional training were subordinated or possibly entirely eliminated in the undergraduate years. Harvard University presents the only example of the trial of such complete elimination. Through seven years before the merging of her graduate school of applied science with the Massachusetts Institute of Technology, Harvard exacted a baccalaureate degree for entrance to courses in engineering. It is possible that the proximity of these two great schools prevented a fair trial of the plan, or it may be that it was too long a step in advance. It is generally conceded, however, that his first attempt at a strictly graduate school of engineering did not prove itself the desired method of correction of the existing imperfections in engineering education.

Undoubtedly the conditions would be greatly improved and the status of the profession of engineering more clearly defined if the formal professional training of engineers were given only in graduate schools. In such circumstances, however, seven, if not eight years of college and university training would be necessary for the student. The necessary probationary period following graduation would doubtless add two or three more, bringing the total to ten years before the student entering college could hope to earn a fair living as an engineer.

Now to a greater extent than in any other profession the student of engineering looks to it as an early means to a livelihood. And this he may safely do, for the profession, also to a greater extent than any other, offers numerous subordinate positions, such as those of draftsman, operator, inspector, etc., all requiring, for a beginning, only a moderate amount of professional training. Further, a sufficient training for these positions may be safely given in a four-year undergraduate course. Indeed, by taking advantage of the flexibility of the elective or group system, this training may be given in a curriculum which differs but slightly from a standard course for a baccalaureate degree in arts and sciences. The common

mistake up to the present has been in the attempt to give a more extensive if not complete professional training in the undergraduate years, with the unfortunate result already described. In many cases, courses of this nature give the student very little more than a high grade of polytechnic training. The student naturally does not realize the limitations of this type of training, and if he can look forward to a degree in engineering from a college in good standing at the end of four years, he is not apt to see the advantage of four years of general studies before taking up the purely professional courses. Every school of engineering in the country now offers professional training in undergraduate years, and many of them confer degrees suggesting professional qualifications on their completion.

The time scarcely appears ripe, therefore, for the strictly graduate school of engineering. The more promising method at present seems to lie in the modification of the existing four-year curriculum, so as to include as much as possible of the present courses in arts and science; in the offering at the end of four years of a degree which indicates preliminary training only, and in the offering of graduate courses and subsequent degrees, indicating the completion of formal professional training.

The Undergraduate Course at Johns Hopkins.

The undergraduate curriculum which has been adopted at Johns Hopkins University with the particular purpose of remedying some of the imperfections which have been mentioned, extends through a period of four years. It is believed that some form of reward should be offered to a student satisfactorily completing this period of work. This reward should not, however, indicate a completion of educational training in engineering, but should serve as a point from which those students who are not qualified either by taste or natural aptitude to continue in more advanced professional study, may nevertheless enter with credit into engineering work under the direction of others. The first three years of this four-year

course will be followed by all students. The first two years will be devoted to mathematics, physics and English, and there will also be one year of work each in modern languages and in chemistry. In the third year there will be three courses, one each in the elements of civil, electrical and mechanical engineering. All three of these courses must be followed by all students. A course in political economy, in which it is intended to introduce the elements of business law, finance and organization, will also be pursued in this year. Mathematics will be continued through one half of this year, and a course in hydraulics will occupy the other half. The fourth year will offer two courses in each of three branches of engineering, specialized professional study being thus restricted to this year. To these will be added a course in logic, ethics, and psychology and one elective such as geology, chemistry, biology mathematics, or other subject. Drawing will be taught through all four years. It will begin with training in free-hand and work uniformly through courses in mechanical drawing up to the graphical treatment of the special problems of the fourth year. Laboratory work in the first two years will be limited to the subjects of physics and one other science. In the last two years the student will divide the time allotted to laboratory work between the drawing room and the engineering laboratory.

Special insistence is made on the training in physics, which extends through two and one half years. A general demonstrational course covering the whole field of physics continues throughout the first year. The class work is accompanied by the carefully organized laboratory course long existent at Johns Hopkins. The second year of work comprises the introduction to the mathematical theory of mechanics, and thermodynamics. In the third year the mathematical theory of electricity and magnetism serves as the introduction to the first course in electrical engineering. In mathematics the first year of work embraces analytical geometry and an introduction to the calculus,—the second being devoted almost entirely to the differential and integral calculus and to special

problems in connection therewith. The half-year course in the third year is in differential equations.

Provision for Practical Work.

Courses in manual training, shop work, foundry work, etc., often found in the curricula of engineering schools, have been omitted from the prescribed work of the college year. It is believed that such instruction as may be necessary in these branches should be obtained at other times. The available time in a course extending through only four years can be spent to much better advantage in class-room instruction or in laboratory work which bears more particularly on the applications of the particular branch of engineering. It is recognized however, that shop work and manual training, thus omitted from the regular instruction, are nevertheless desirable and it is intended to provide opportunity for them during the summer months. All students will be encouraged to seek contact with professional work during this period, and effort will be made to secure occupation for as many as possible. Should the plans which have been made in this direction develop satisfactorily, one of the requirements for graduation will be that a student shall have passed at least four months in a manufacturer's shop, in the employ of some public utility corporation, in the office of a consulting engineer or in some other occupation bringing him into direct contact with the application of engineering principles. During one of the summers a part of the training in civil engineering will consist of a course in surveying. This course must be followed by all students and it is intended to have it follow immediately after the close of the academic year.

Summary of the Undergraduate Course.

Briefly summarized, this course differs but slightly from a course leading to the degree of bachelor of arts with mathematics and physics as principal subjects, and with courses in engineering substituted for the usual electives. The student will know something of each of the three principal branches

of engineering, and will have had two successive years of study in these branches. While, under this plan, the special instruction in a particular branch of engineering is somewhat curtailed when compared with that of the other better-known engineering schools, the greater number of educational studies and the better fundamental training are obtained at the expense only of courses covering advanced theory and the analysis of special applications of the different branches of engineering. It is believed that with increased insistence on underlying scientific studies, and on the central principles of the different branches of engineering, familiarity with such special applications as the student may have missed in his four-year course will follow promptly without trouble when he encounters them at a later date, and a substantial foundation will have been laid for subsequent study of advanced theory. It is also believed that the graduate will be quite as well, and probably better, prepared for beginning engineering work under the direction of others, than graduates of those schools in which professional instruction begins early in the course, to the sacrifice of educational studies, and in which the effort is made to take a complete survey of the entire field of a particular branch of engineering during four-year course.

The general character of the new course may be understood from a comparison with those of five of the better-known schools of engineering in the East, on a basis of the proportion of the total time allotted to each subject. This comparison has been made in detail for all subjects. For the purposes of this discussion all the subjects may be divided into three groups: (1) general educational and cultural studies; (2) scientific studies underlying professional courses, being principally mathematics and physics, and (3) professional studies. In the new course in the Johns Hopkins University the studies of group (1) consumes 24 per cent. of the total time; the percentages in the five institutions studied vary from 2 to 16 per cent. For group (2) the percentages are; Johns Hopkins, 42 per cent., other institutions, from 30 to 40 per cent. For

group (3), professional studies, Johns Hopkins, 30 per cent., the other institutions, from 45 to 58 per cent.

Graduate Work.

While the university has thus given most careful consideration to the problem of the creation of an undergraduate school, it has nevertheless had constantly before it the question of graduate activity in the field of engineering. As already stated, the conditions of the legislative bill are extremely liberal, leaving the university practically unhampeed as to the particular direction and character which should be given the work of the new school. The bill, in fact demands an " advanced " character for the school. It would be possible, under its liberal terms, to devote pactically the entire resources provided to the development of graduate work. In the light of the university's history and traditions this plan has in fact appealed strongly to a number of its members. However, from the survey made by the committee which studied this phase of the question, it did not appear evident, for reasons which have been already mentioned, that a strictly graduate school of engineering could be introduced at this time with a prospect of success unless accompanied by a carefully planned undergraduate school from which material might be drawn. Further, the discussions during the time the legislative bill was under consideration, the conditions surrounding the award of the scholarships provided, and several other features of the bill make it certain beyond all question, that its obvious intent was that an undergraduate school should be an integral part of whatever plan might be adopted.

While, therefore, it has appeared advisable to give first attention to the creation of an undergraduate curriculum, the development of an accompanying graduate school is considered one of the most important ultimate aims, and announcement has been made of the courses and facilities for graduate study. In the graduate school, opportunity will be offered the student to procure complete formal training in any single direc-

tion he may elect within the three branches: civil, electrical and mechanical engineering. The graduate courses will cover not only the special applications omitted from the undergraduate courses, but will also include discussion of the progress of engineering achievement. Important features of this work will be the continual review of current engineering literature and also the conduct of a seminary in each branch of engineering. In this way contact will be maintained with the present state of engineering practice and achievement, and the student will develop, and present evidence of his ability to make comprehensive review and study of special problems.

It is in connection with the graduate work that the university expects to identify the department of engineering with its history and traditions. Experimental investigation and research will be encouraged in every possible way. The organization of the work will be such as to enable the professors to devote a large part of their time to the guiding of the students in this work, and to the taking of active personal part therein. The new laboratories are being particularly designed to provide, in addition to the requirements for the undergraduate work, special rooms and equipment to meet the needs of experimental investigation. It is hoped that intimate relations may be developed with the State and municipal activities requiring the services of engineers, and also with manufacturing companies with the aim to study their special problems, and to open promising lines of experimental research.

Degrees and General Organization.

At the end of the four-year undergraduate course a baccalaureate degree will be conferred which will indicate preliminary training in engineering. The graduate courses will lead to the degrees in civil engineering, mechanical engineering and electrical engineering, two years after graduation in the undergraduate course of this university or their equivalent. Should the student desire to proceed further with special study and investigation, the degree Doctor of Philosophy will

be open to him, subject to the regulations of the university in connection with that degree.

The department of engineering is an integral part of the organization of the university. The general and fundamental studies of undergraduate years will be conducted in the same class-rooms and laboratories and by the same professors as those of the corresponding courses in the college of arts and sciences. The undergraduate work of the first two years will be under the direction of the Board of Collegiate Studies. The professional studies of the graduate and undergraduate period will be directed by the faculty of engineering, under the direction of the advisory committee of the department of engineering. This committee, consisting of the president of the university and eight professors, will make recommendations through the president to the trustees on all questions pertaining to the conduct of the department.

Beginning in October, 1914, all professional studies, laboratory work, and research will be conducted in the new laboratories at Homewood, the beautiful site in the northern section of Baltimore, to which the university is now in process of removal. The design of the laboratories has been most carefully studied, and they will be equipped with every facility for carrying out the purposes which have been briefly outlined in this paper. A detailed description of the laboratories has already appeared in several other publications.

PROPOSED COURSES IN STRUCTURAL ENGINEERING FOR CIVIL ENGINEERING STUDENTS.

BY W. M. WILSON,

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INTRODUCTION.

The civil engineering department of the University of Illinois is about to put into effect a revised course of study. Befor doing this it has seemed advisable to make a careful study of the field of structural engineering to ascertain what portions of the work should be presented to the student and the best method of instruction to be used. The course as outlined has not been adopted by the department, but represents the writer's idea of what such a course should be if it could be made to coordinate properly with the other work of the engineering college. The work is intended for students who wish to specialize in structural engineering. Students in civil engineering not wishing to specialize in structural engineering should be given an option of other groups of related subjects.

A course in structural engineering should include instruction in the selection of the type of structure; the principles involved in the design of a structure from the footings to the completed superstructure; the application of these principles to actual design; and sufficient practice in making working drawings to familiarize the student with details of construction.

The instruction should be given in such a manner as to provide mental training; develop initiative and give sufficient practice in the execution of details to make the student of some economic value in engineering work immediately upon graduation. In making up the course which follows, the writer has endeavored to apply these principles in such a way as to best utilize the time available.

The course as worked out is given in the following summary. The number of semester hours devoted to this part of the work agrees with the number provided by the department in the proposed new course of study.

SUMMARY.

Junior Year, Second Semester.

Stress Analysis.—The determination of stresses in bridges and buildings by graphics and analytics. Two three-hour drawing-room and three one-hour recitation-room periods per week. Credit, 5 semester-hours.

Structural Details.—Use of hand-book, reading blue-prints, writing shop bills and making details of connections and main members of steel bridges and buildings. One three-hour drawing-room and one one-hour recitation-room period per week. Credit, 2 semester-hours..

Senior Year, First Semester.

Bridge Design.—Designing, detailing and writing shop bills for steel railway bridges. Three three-hour drawing-room periods per week. Credit, 4 semester-hours.

Masonry.—A study of the various materials used in masonry construction, types of structures, testing materials and designing. Two three-hour laboratory and three one-hour recitation-room periods per week. Credit, 5 semester-hours.

Stresses in Reinforced Concrete.—A theoretical study of the stresses in reinforced concrete structures. Two one-hour periods per week. Credit, 2 semester-hours.

Advanced Stresses.—A theoretical study of deflection and of the stresses in complex steel structures such as continuous girders, arches, movable bridges, suspension bridges, portals, and structures having rebundant mebers. Three one-hour recitation-room periods per week. Credit, 3 semester-hours.

Second Semester.

Building Design.—Designing and detailing steel mill and office buildings. Three three-hour drawing-room periods per week Credit, 3 semester-hours.

Reinforced Concrete Design.—The design of reinforced concrete retaining walls, bridges and buildings. Two three-hour drawing-room periods per week. Credit, 3 semester-hours.

History of Structural Engineering.—A historical sketch of the various types of structures which have been used. One one-hour lecture per week. Credit, 1 semester-hour.

DESCRIPTION OF COURSES.

The work in stress analysis should consist of the determination of stresses in simple steel structures by graphic and algebraic methods. These methods have been combined in one course because it seemed more desirable to emphasize the determination of stresses than to give an extended course in either analytics or graphics. Where the two methods are given separately there is a temptation to give different applications of a method rather than to give the best solution of a particular problem. A larger amount of work applicable to the practical design of structures can be presented in a limited amount of time by presenting the two methods simultaneously than by presenting them as separate courses.

Lessons should be assigned in the text and the recitation period utilized to help the student to understand the subject matter presented. At the same time, problems should be assigned for the student to solve during the drawing-room period under the supervision of an instructor. By having the problems solved in the drawing-room it is possible for the instructor to make oral suggestions while the work is being done which is much better than criticizing work already done incorrectly.

Each student should be required to determine the stresses due to dead load, live load and wind load in the following

structures: roof truss, steel bent of a building, through girder, deck girder, and Warren, Pratt and bowstring trusses.

The work in structural details should consist of instruction in the method of making up sections of members and in the method of designing details to connect the different members which make up a structure.

The student should be assigned problems to familiarize him with the various shapes of structural steel manufactured and with the tables of information found in the steel hand-books. He should then be given shop drawings of various members of different structures and required to write shop bills. This would give him practice in reading drawings, and make him familiar with the methods of billing material and of making up various members. He should then be given data governing the design of various members and required to determine the sections. After becoming familiar with the make-up of sections of main members, he should be given a shop drawing of various connections and required to compute their strength after which he should be given the sections of members and required to design the connection.

The details of both buildings and bridges should be included in this course..

The work in bridge design should consist of the design of railroad bridges. Each student should be required to make a set of design calculations, a design drawing, a shop drawing and a set of shop bills for one plate girder span; a set of calculations, a stress sheet and a shop-detail drawing of the stringers and floor-beams of a through-truss riveted railroad bridge and to check a set of similar calculations and drawings. Students desiring to do more than the minimum amount of work required should be given an opportunity to make a design drawing of the trusses.

In most of the studies which the student has had up to the end of the junior year, instruction has been given in detail. This has given him a knowledge of the sciences and has given him discipline in the execution of work. He has not had prac-

tice in choosing proper values for factors upon which design depends. He may be able to design a deck-plate girder span 60 ft. long with girders 7 ft. deep and 6½ ft. apart but may not know why a deck plate girder was used or why the dimensions were fixed at the values given. This course is intended to give some practice in exercising judgment in the determination of those factors. In order to do this, in assigning problems in bridge design instead of fixing all the factors upon which the design is based, the student should be given a field survey of the bridge site and required to design a crossing. This makes it necessary for him to choose the type of bridge and fix all dimensions.

The course in masonry should be devoted to the study of masonry construction. Sufficient recitations, quizzes, problems, designs and laboratory tests should be required to make it necessary for the student to learn the most important principles and to learn where to find and how to apply the large amount of information available. During the first half of the semester both laboratory periods should be devoted to testing materials. The student should be required to test samples of cement to see if they conform to specifications; to test samples of mixed sand and gravel to determine the amount of either one or the other to be added to give the resulting mixture the proper proportions of the two materials; to test the various masonry materials to determine their physical properties, and to make a test of the bearing power of soil.

This work makes the student familiar with the method of conducting tests such as are made of the materials used in large and important structures. It also gives him a first-hand knowledge of the materials and of the specifications which could be obtained in no other way.

During the second half of the semester the two laboratory periods should be devoted to the design of masonry structures. Each student should design a bridge pier, a bridge abutment and the foundation for a building, each design to include a working drawing and a scheme for construction.

The courses in stresses in reinforced concrete should be devoted to the theory of such stresses and, in addition to developing the theory, the student should be required to make the calculations for the design of such elements of construction as girders, slabs, columns, etc.

In advanced stresses attention should be devoted to the determination of stresses in the more complex structures. The course should include general study of such subjects as continuous girders, suspension bridges, movable bridges, arches, portal bracing, structures having redundant members, deflection and secondary stresses. In addition to giving the student a general knowledge of this broad field, he should be required to make a thorough study of the stresses in one or more of these more complex structures.

The course is made up largely of advanced mathematics and is apt to be unpopular. It should therefore be administered in such a way as to stimulate interest, not only so that the students may do good work in class but, if possible, so that there may be created in them a desire for further investigation.

The course in building design should be devoted to the design of steel buildings. The theory for determining the stresses and the method of making details have been covered in earlier courses. It remains to apply the knowledge gained in these courses to the design of buildings. Each student should be required to design at least two buildings, one a steel skeleton mill building and the other a steel skeleton office building.

In designing the mill building each student should be given the overall floor dimensions of the building and the purpose for which it is to be used. He should be required to outline the general scheme of the building such as the number of bays, type of columns, trusses, etc. After the general scheme has been approved by the instructor the student should be required to make a stress sheet and typical details.

In designing the office building the student should be given

a plan showing the column spacing and an elevation showing the number of stories and the clear height of each. He should be required to decide upon the type, and make the design for the floor, roof and spandrel walls. Each man should be required to make floor plans, wind calculations, column loads, and column schedules. The more ambitious should have an opportunity to do additional work by carrying out the design in detail.

In the course in concrete structures each student should be required to design a through or deck-girder bridge span, a retaining wall and a building. The design of each structure should consist of a complete set of calculations and design drawings. Students able to do more than the minimum amount of work should detail the reinforcing bars, estimate the quantities of material and design the forms.

The historical sketch of the development of structural engineering should cover the various steps in the development of the present types of structures and the advantages of the succeeding types. Considerable time should be devoted to describing the more important types of structures being built at the present time and to pointing out the conditions to which each is most adaptable.

Suggestions for Administering the Courses.

A great deal of the work, as outlined above, is to be taught in the drawing-room. The success of any course depends largely upon the method by which it is administered. Drawing-room courses have been in general use for only a short time as compared with recitation-room courses and the best method of administration has not been so carefully worked out. Considering the opportunities which the drawing-room offers for efficient personal instruction, courses in drafting are too unpopular. The subjects taught are recognized by the students as being important and should be interesting to one preparing to enter the engineering profession. This being true, it would seem that any unpopularity which attaches

itself to such a course is largely the fault of the method by which it is administered.

The writer wishes to make the following suggestions relative to the administration of drawing-room courses.

1. Insist upon thorough training in the prerequisite subjects so that it will be unnecessary to make any extended review of ground already covered. If too much time is given to such a review, the better students who already have the work well in hand will conclude that the course is to be only a "rehash" of what they have already done, and will lose interest. The leaders must not be discouraged as they are the ones who are depended upon to put life into the class and pull the others along with their enthusiasm.

2. Make all assignments clearly so that the student knows exactly what he is to do. This does not necessitate, however, giving so much information that there is nothing left but a problem in mathematics. The assignment may be clear and concise and yet a number of factors may be left to the judgment of the student. What is desired is that he understands clearly the end toward which he is working. If arbitrary restrictions on the solution are desirable they should be clearly stated, but it should be understood that if no such restrictions are specified the student is subject only to the general rules governing good design.

3. Instruct the student how to do the work. Men in engineering offices, doing the same thing over and over, have gradually evolved what they consider to be the best method. The instructor should acquaint himself with this method, convey the information to the students and insist upon their applying it to their work. By insisting that the student work in accordance with a carefully prepared plan he learns the most efficient way of working, covers more ground during the course, has the discipline of following instructions and the work is in a shape much more satisfactory to both student and instructor. The loss of experience in working out a

scheme of attack for himself is more than offset by the benefit derived from following out a well-planned scheme.

To help the student follow the prescribed method, sample calculations and sample drawings should be available for him to refer to.

4. The instructor should keep in touch with the student's work as it progresses to see that he is working along the right line. It is not enough to look over a finished drawing and mark the mistakes, as a basis of giving a grade. It should be examined while it is being made and the difficulties analyzed, the teacher pointing out the detail that is wrong, showing why it is wrong and explaining how it should be corrected.

5. Numerical accuracy should be insisted upon. Having the calculations made in a neat and orderly manner promotes accuracy. Having the students check each other's work is good training for them and relieves the instructor of a large amount of drudgery.

If the instructor conducts his class in the manner outlined above, his course will be valuable and interesting. However, such close supervision on his part will be exhausting labor and it will be necessary to reduce the number of hours of drawing-room instruction required of him to a reasonable value.

Conclusion.

These courses as described conform to the requirements as set forth at the outset. Some phases of the work which it would be desirable to include have been omitted because of lack of time. Chief among these are practice in making estimates of cost, more practice in the determination of stresses in complex structures, especially arches, and practice in making shop drawings.

Some experience in estimating the cost of structural work might well be included in a course in cost analysis which should be included in a civil engineering course. The amount of time required to determine the stresses in a complex struc-

ture is so great that it is impossible to do much along this line. As was pointed out before, all that can be accomplished is to take up the several structures in general and perhaps one in detail and to try to create interest on the part of the student for further investigation. For practice in making shop drawings the student must wait until he gets into commercial work.

MECHANICAL ENGINEERING AT COLUMBIA UNIVERSITY. THE NEW GRADUATE COURSE.*

BY CHARLES EDWARD LUCKE,

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Since the establishment of the so-called standard American four-year course of study for the professional degree of mechanical engineer, about a half century of time has passed. In that time the profession has advanced far more, in intensity and complexity of problems successfully solved, in methods of attack developed and adopted, and in participation in general industrial affairs, than for the whole period of its previous history. The four-year course of study is still the standard preparation in spite of the fact, nowhere disputed, that the sort of preparation needed today is vastly different from what was satisfactory when the present older schools were established. More or less general efforts have been and are being made to adjust the work of the professional school to the requirements of practice along lines as numerous as the men or schools engaged in the work, so that while the four-year period is still the standard, the disposition of that time is most varied, far more so than mere catalog announcements would lead the casual reader to believe.

The latest and probably the most radical of these attempts to raise the standard of preparation to somewhere near the requirements of present day professional practice is that of Columbia University. According to this new plan all students, beginning with 1915, are required to pursue a prescribed course of engineering study for three years after fulfilling, under the academic department or college, the requirements of a series of preparatory or introductory subjects which nor-

* Abstract of paper which contains detailed descriptions of all courses covered in the tables.

mally require three years for completion and equivalent to those for the B.S. degree. This new plan is identical in general scope with Columbia's solution of the similar problem in the professional schools of law and medicine. Just what reasons have led to the adoption of this system for the training of engineers is not at the present times a matter of so much general interest to engineers, engineering instructors, and other schools, as is a statement of just what is to be done with the time available; the *why* and *wherefore* of the plan may be found in the statement of what it is, here presented for the first time.

Subjects required for entrance and to be studied in the more or less standard science college course, fall under three classes: first, those that are primarily cultural; second, those that constitute essential preparation for the study of mechanical engineering; and third, those that serve to bridge the gap from a purely preparatory to the real engineering point of view and are properly introductory engineering courses. The time devoted to each is indicated by points, one point being one hour per week per term, or 14 hours total for lectures or recitations, twice this for drafting room and three times for shop or laboratory.

ENTRANCE SUBJECTS FOR THE GRADUATE COURSE IN MECHANICAL ENGINEERING.

Group I. Cultural.

Subject.	Points.
A. English	9
B. Philosophy	6
C. French or German	6
D. History	6
E. Economics	3
F. Political Science	3

Group II. Preparatory.

Subject.		Points.
G. Mathematics	Algebra	3
	Analytical Geometry	3
	Calculus	12

H. Physics	Mechanics and Wave Motion	6
	Heat and Light	6
	Electricity	6
	Laboratory	3
I. Chemistry	General Inorganic	10
	Qualitative Analysis	10

Group III. Introductory.

Subject.		Points.
J. Drafting	Mechanical Drawing	4
	Descriptive Geometry	3
K. Analytical Mechanics		2
L. Mineralogy		3
M. Theory of Surveying		2
N. Shop Work		320 hrs.

SUBJECTS OF COLUMBIA GRADUATE COURSE IN MECHANICAL ENGINEERING.

First Year.

Department.	Subject.	Total Hrs.
PHYSICS:	1. Physical Laboratory	42
	2. Advanced Heat	42
	3. Analytical Mechanics	84
CHEMICAL ENGNG.:	4. Industrial Chemistry	84
	5. Engineering Chemistry	98
METALLURGICAL ENGNG.:	6. Metallurgy of Iron and Steel	28
	7. Metallurgical Laboratory	42
CIVIL ENGNG.:	8. Hydraulics	28
ELECTRICAL ENGNG.:	9. Management of Electrical Machinery	28
	10. Elements of D. C. Electrical Machinery	28
MECHANICAL ENGNG.:	11. Power Machinery	98
	12. Machine Elements	98
	13. Shop Processes	140
	14. Mechanical Instrument Laboratory	42
	15. Hydraulic Laboratory	42
		924

55 per cent. of which are in class.

	16. Summer Shop Work	200
	17. Manufacturing Shop, Inspection and Report	120

Second Year.

Department.	Subject.	Total Hrs.
CIVIL ENGNG.:	18. Resistance of Materials	112
ELECTRICAL ENGNG.:	19. Electrical Distribution	28
	20. Alternating Current Engineering..	28
	21. D. C. Laboratory	56
MECHANICAL ENGNG.:	22. Engineering Thermodynamics	196
	23. Mechanics of Machinery	154
	24. Proportions of Machine Elements..	154
	25. Machine Tools	28
	26. Pumping Machinery	28
	27. Air Machinery	28
	28. Compressor and Fan Laboratory..	56
	29. Heat Transfer Laboratory	56
		924

55 per cent. of which are in class.

	30. Design of Machinery	200
	31. Commercial Power Plant, Inspection and Report	120

Third Year.

Department.	Subject.	Total. Hrs.
ELECTRICAL ENGNG.:	32. Electric Motor Drives	42
	33. A. C. Electrical Laboratory	56
LAW:	34. Business Law	28
	35. Steam Turbines	70
	36. Reciprocating Steam Engines	70
	37. Industrial Heating and Cooling...	42
	38. Water Power	84
	39. Steam Power	140
	40. Steam Power Laboratory	56
	41. Gas Power	56
	42. Gas Power Laboratory	56
	43. Factory Construction and Equipment	154
	44. Manufacturing Processes and Management	70
		924

55 per cent. of which are in class.

COORDINATION IN ENGINEERING INSTRUCTION.

BY A. B. McDANIEL,

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Although the writer is still a novice in the field of engineering instruction, having just completed his eighth consecutive year of teaching, certain features of this department of the pedagogical field have aroused his especial interest. There are two general divisions of the subject which will be discussed; first, the correlation of subjects taught, and second, coördination in the departmental organization.

Correlation of Subjects.

Coming directly from several years of intensive practical experience and entering upon the duties of a teacher in a large technical school, the writer was soon impressed by the lack of coördination and correlation between the different departments and the subjects taught. The curriculum seemed like a bill of fare of a quick-lunch restaurant, where the strenuous patron bolts a series of ill-assorted dishes. Perhaps this accounts for the large amount of mental malnutrition which is prevalent among our students. The amount of unrelated and unassimilated knowledge which the average technical student possesses upon his graduation is astonishing. This knowledge is generally in the form of abstract facts and ideas which the young, inexperienced graduate is unable to apply to practical purposes. He has knowledge but lacks the power of application. The late C. R. Crane, of Chicago, made a vigorous and to some extent a justifiable attack upon the technical schools of this country. One of his chief contentions was the impracticableness of the training which the technical or engineering student received. Recently J. J. Hill made the statement

that collegiate instruction is indefinite and inaccurate. The speaker has had the supervision of a large number of young technical graduates during the past ten years in practical engineering work. He well remembers the case of a graduate of the civil engineering department of one of the largest and best known state universities, who could tell him about the convergency of meridians and yet could not correctly check up a traverse for a proposed drainage canal twenty miles in length. This is but one of a large number of observed instances all of which point out the folly of teaching a subject in a purely theoretical manner. All subjects should be so taught that the knowledge gained may be intelligently applied in practice.

The lack of coördination is especially noticeable in the studies of the freshman and sophomore years when there are a large number of non-professional and cultural subjects taught. The latter are generally taught by academic teachers who have had little or no technical training and experience. In recent years, some very valuable and instructive papers on instruction in English for engineering students have been presented before this society. Still more recently the subject of mathematics has been taken up and discussed. An interesting and valuable syllabus is one of the concrete results of this discussion. A fair question is; 'Has this syllabus been adopted into any schools and if so have any efficient results been achieved?' Let us consider further this subject of engineering mathematics and for this purpose the writer will present his ideas based on a recent experience.

During the first part of the freshman year, the student is taught plane trigonometry. This is followed in the second half of the freshman year or in the early part of the sophomore year by a course in plane surveying, and in the junior year by a course in railroad engineering. The trigonometry is often taught by a teacher who has very little knowledge of engineering and furthermore does not take the trouble to inform himself concerning the courses in which his students must soon apply their knowledge of mathematics. The aca-

demic teacher uses one of a number of well-known text-books and assigns in the usual routine way a series of lessons and problems from which the student is supposed to derive at least a working knowledge of the subject. Generally, the speaker has found the student equipped with a vague idea of the trigonometric functions. Beyond the fact that they are certain abstract fractional forms, they mean very little to him. He does not readily see their significance in the solution of problems on paper, and in the field. Especially is he deficient in the ability to visualize these fundamental trigonometric concepts and quickly grasp their applicability. The reason for this is clear. *The subject is taught in an abstract way and not in correlation with the dependent branches of engineering.* Some schools, notably the college of engineering of the University of Minnesota, have endeavored to solve the problem by employing teachers with engineering training for the courses in mathematics. This method has proved to be quite satisfactory and efficient. Unquestionably such teachers vivify the subject, and present it in a concrete manner, having always in mind the future applications of the principles which they are drilling into the minds of the students.

During the writer's first year in teaching surveying and railroad geometry in a department of civil engineering in a western state university, his attention was often drawn to the inadequate preparation of the students in mathematics. However, the department of mathematics there was considered strong and efficient. It was often found necessary in the classes in surveying to devote several whole exercises to instruction in mathematics. The second year brought a change in the head of the department of mathematics and the speaker took occasion to hold several long conferences with the new teacher, who expressed a sincere desire to coöperate in securing greater correlation of subjects. The instructors of the department did coöperate in this work by requiring the students to work out a large number of practical problems, and required the use of the chain, compass and transit for the

solution of simple geometric and trigonometric problems in the field. The increase of actual working knowledge of the average student was noteworthy and resulted in a greater enthusiasm and capacity for the engineering subjects.

The course in plane surveying was thrown open to students from other colleges and generally the writer would have several non-technical students in each class. These students had very inadequate and limited previous instruction in mathematics, especially trigonometry, and it was deemed advisable to give considerable drill in those principles of geometry or trigonometry which applied to the lesson on hand. The students were first made familiar with the construction and use of the surveying instruments. Then they went into the field and laid out simple geometric figures and by the use of the tape, compass and transit, they soon became familiar with various methods of measuring lines and areas. The trigonometric functions became comprehensible relationships and useful tools. After a thorough mastery of the elementary principles, the students were given more complex problems in land and railroad surveying. It was both surprising and gratifying ing to note the facility with which the average student acquired a practical working knowledge of mathematics under this coördinate system of teaching. The non-technical students attained average, and in many cases high rank in the courses. The students seemed to develop an unusual amount of self-reliance and self-confidence and were eager to put in a large amount of extra time in solving the more difficult field problems.

The subject of calculus as generally taught is a waste of time. The average student, two years after graduation, cannot do a simple integration. Several years ago, while the speaker was employed in the office of well-known consulting structural engineers, it became necessary to compute distances along elliptical hip and valley girders of a steel hemispherical roof. Of thirty technical graduates in the office, only three had any definite conception of how to do this. Calculus should

be taught by the graphical method and especial emphasis laid upon the solution of problems which often arise in practical work.

Least squares and differential equations mean very little to the average student, when taught in the ordinary routine, academic way. But let the fundamental principles of these subjects be applied to the solution of problems in geodetic surveying, precision of measurements and the design of electrical machinery and they become live and vital to him.

The rational method of procedure in teaching is to give a student a problem and to suggest to him, generally by questions, the way to attack it and the tools to use. After he has solved a few problems in this way he will understand and appreciate the underlying principles and the philosophy of the subject. Fundamenal truths learned in this manner will be remembered long after abstract statements of fact are forgotten.

Many will doubtless claim that the foregoing suggestions will tend toward an undesirable commercialization of technical education and that the mental training and cultural development to be derived from the study of pure mathematics must not be lightly disregarded. The writer does not underestimate mental training *per se*, but efficient technical instruction demands something more than the mere exercise of the brain and storing up of abstract knowledge. The *sine qua non* of efficient engineering instruction is the development of mental power in the students. They should be equipped with sufficient energy and ability to apply the fundamental principles which they learn in the class-room to the solution of practical problems. This equipment will result only from the simultaneous acquisition of abstract facts and a knowledge of their uses.

To recapitulate, it is the writer's belief from his study and experience, that elementary mathematics (and perhaps the advanced branches) can be taught to the engineering student more efficiently and economically, in coördination with engineering subjects. The teaching should always be done by an

engineer having a thorough training in mathematics and a wide experience in the field of engineering.

Coördination of Department Organization.

In the second part of this paper, coördination in engineering instruction from the viewpoint of departmental organization will be discussed.

Let us consider a department of civil engineering of a typical college of engineering in a large State university. The department is composed of several sub-departments such as, railway engineering, structural engineering, highway engineering, hydraulic engineering, etc. Each sub-department has a head and several subordinate teachers, and all are directly subject to the authority of the head of the department. All this sounds like an efficient, business-like organization in which would be found the closest coördination, and harmony of coöperative association. But unfortunately such generally is not the case.

The head of the department is its chief executive, and represents the department in the higher administrative councils of the university. Generally the larger part of his time is taken up with the minutiæ of administrative affairs. He rarely, if ever, visits a class and is generally uninformed in regard to the teaching ability of his instructors. Occasionally the head professor will base his opinion of his subordinates upon mere hearsay, such as student criticism.

Department meetings are held spasmodically or at infrequent intervals. Such occasions are often formal ratification meetings of the policies and acts of the department head. There is ordinarily felt such a feeling of repression and constraint especially among the younger members of the staff, that freedom of thought and effective speech is impossible. Hours of valuable time are often consumed in profitless discussion about trivialities. Dignified professors will ponder and quibble over technicalities to an extent that would shame a lawyer's association. Matters of this character could and

should be settled by an intelligent clerk under the supervision of the department head.

Primarily the organization centers in the arbitrary authority of the head professor. The subordinate teachers act as a number of independent units, each one supreme in his own sphere of activities and ignorant of the work and ideals of his associates in coördinate lines of work. The results are inefficient teaching, inadequate preparation of the student for subsequent courses, and duplication of work. Such a condition of affairs would never be tolerated in an efficient business organization.

The writer has suggested some of the elements which lead to weak and loose departmental organizations. During the time that he was professor of civil engineering in a western State university, he also was the directing head of an engineering company. The thought had often occurred to him that some of the methods used in such a company could be successfully applied to the organization of an engineering department of a technical school or college of engineering. For example, in our engineering company, every employee handed in a complete report at the end of each day's work. Why should not every assistant, instructor and professor hand in weekly reports to the head of their department? Such reports should state the hours of class-room, laboratory, and field work; the character and extent of the ground covered, notes on the work of students; recommendations concerning changes in courses, method of teaching, etc. At the end of each week there should be a meeting of the department, or sub-department heads to consider matters of administration. A careful consideration of these weekly reports would afford the administrative officers and especially the head of the department, a comprehensive idea of the work done in the department during the preceding week. The reports would also indicate the amount of time which each instructor was giving to the various phases of his work, the results accomplished, the industry and initiative shown, etc. Such in-

formation is necessary in the consideration of the promotion of various members of the staff.

As a chief engineer of a large engineering company or project occasionally makes personal inspection trips to the various parts of the work going on under his direction, so the department chief should make inspection trips to the various classes held in recitation room, laboratory and field. This is rarely done, yet the speaker is unable to understand how a professor in charge can have an accurate conception of the character and scope of work going on in his department without such inspection. Further, the occasional visiting of various classes by the instructors of the department would inform them as to the work which other members of the staff were doing and how they were doing it.

The accompanying diagram on the sheet before you is a sug-

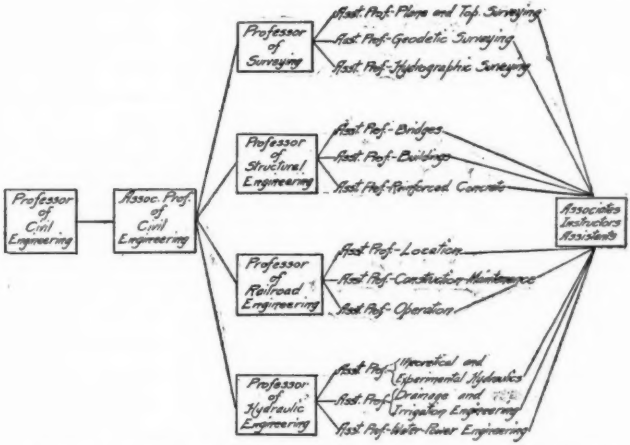
Professor of Civil Engineering
Assoc. Prof. of Civil Engineering
Professor of Surveying
Asst. Prof. Plane and Top. Surveying
Asst. Prof. Geodetic Surveying
Asst. Prof. Hydrographic Surveying
Professor of Structural Engineering
Asst. Prof. Bridges
Asst. Prof. Buildings
Asst. Prof. Reinforced Concrete
Professor of Railroad Engineering
Asst. Prof. Location
Asst. Prof. Construction Maintenance
Asst. Prof. Operation
Professor of Hydraulic Engineering
Asst. Prof. Theoretical and Experimental Hydraulics
Asst. Prof. Drainage and Irrigation Engineering
Asst. Prof. Water-Power Engineering
Associate Instructors Assistants

Diagram of Proposed Organization of a Department of Civil Engineering

gestion as to the organization of a department of civil engineering. It should be noted that some branches, such as hydraulic engineering, are in some schools under another depart-

ment, such as mechanics or mechanical engineering. The writer has not tried to include every branch of civil engineering, but simply a few of the more important to illustrate the schemes of the proposed organization which will be now outlined.

The head of the department is the chief executive and has general authority and supervision over the department. His position corresponds to that of chief engineer of an efficient organization.

The associate professor corresponds to the position of principal or chief assistant engineer of an engineering organization. His duties are to have direct charge of the active work of the department such as keeping in active touch with the heads of the sub-departments, visiting classes, inspection and maintenance of equipment, apparatus, supplies, etc. He is directly responsible to the head of the department for detailed and complete information at stated intervals concerning any phase of the departmental activities. Neither the professor or associate professor should have a large amount of routine teaching to do. The associate professor becomes acting head of the department during the absence of the head.

Each department has its head, or professor, and assistants such as assistant professors, associates, instructors and assistants. Each professor is reponsible for the efficient and economical operation of his sub-department and his position may be said to correspond to that of resident or division engineer of an engineering organization. Each sub-department has its regular weekly meetings which all members are required to attend. Each member presents a weekly report filled out on standard (filing-card-size) form. The report states: subjects and number of hours taught in class-room, laboratory, and field; character and extent of ground covered; recommendations and suggestions as to presentation of courses; requests for equipment, supplies, etc. The reports and matters of sub-departmental interests are discussed.

Bi-weekly department meetings are held and attended by the head, associate professor and the head professors of the

sub-departments. At these meetings the sub-heads present reports covering the work done in their departments during the previous two weeks. Individual reports of the instructors may also be taken up and discussed. Matters of importance effecting the administration and operation of the whole department will be considered at these meetings.

In the college of engineering will be the departments of civil, mechanical, electrical, mining, chemical, sanitary, and other branches of engineering. Each department will be in charge of a professor and an associate professor who will all be under the authority of a dean and an assistant dean. The former is in responsible charge of the administration of the college. The assistant dean is in direct charge of the administrative details of the college and keeps in close personal touch with all the departments.

Monthly meetings of the college assembly are attended by the dean, assistant dean, heads and associate heads of all departments and of the allied departments such as mathematics, physics, chemistry, etc. At these meetings each department head submits a report and matters of general college interest are dealt with.

As a part of the college organization, there should be a number of committees, working under the assembly, in consulting and advisory capacities. Every member of the staff should be a member of some one of these committees and appointed by the assembly, after a consideration of the written preferences of all the members. These committees shall be on student credits, athletics, college extension work, etc. The activities of these committees should largely shape the policies of the college and all its departments. Thus every member of the staff would feel a personal interest in the welfare and progress of the college. There would be an inducement for the cultivation and exercise of real intelligence and high ideals and the routine of class-room work would be coördinated with the administrative functions which govern it.

The above is a merely suggestive outline for the organization of a department and the coördination of the various

departments of a college of engineering. Its purpose is to secure higher efficiency, better coördination, and more real democracy than are now generally existent in such institutions. The college, if it fulfills its complete function, should primarily educate its students to become efficient, broad and high-minded engineers and citizens. This requires that the whole staff and especially the higher administrative officers shall be men of vision, enthusiastic in their work, daily inspirers of high ideals of character and ability in their students and leaders in their various professions.

Another function of the college is to contribute a generous share to the scientific knowledge and understanding of the profession of engineering. To this end, each department and sub-department should have a research man whose whole time and attention shall be given to the investigation of original problems. The members of each department should coöperate with their research man in the suggestion and solution of problems in which they are interested. However, the research man should not teach and the other members of the staff should give their main thought and attention to the instructional side.

A third and highly important function which the college should perform is that of public service. This has taken the form of university extension work in several of the well-known state universities. A college of engineering of a state university should be of real service to the state in the development of its resources and the widespread promulgation of scientific information among the people. The staff of the college should be represented on the engineering and public service commissions and departments of the state. An active publicity bureau should supply the press and literature of the state with information concerning the college activities and especially with articles of practical scientific interest to the people. Bulletins describing the results of original investigations should be issued from time to time, primarily for the enlightenment of the people and not as a method of educational advertisement.

A STUDY OF TECHNICAL COLLEGE CATALOGUES WITH RESPECT TO DESCRIPTIONS OF COURSES OF STUDY AND OF INSTRUCTION.

BY HENRY S. JACOBY,

Professor of Bridge Engineering, Cornell University.

As a member of the committee on advanced standing of the college of civil engineering in Cornell University for over fifteen years, a large expenditure of time and effort has been required in the attempt to evaluate the relative equivalence of courses of instruction in many of the technical colleges of the United States and Canada. These studies have emphasized the excessive diversity in the form, arrangement and description of this material as printed in the registers or catalogs of the various institutions. Many of these catalogs have no indexes whatever, while others have indexes which are more or less inadequate. The order in which the departments of instruction are arranged is sometimes alphabetical but more frequently the order has been determined by the historical development of the institution, and is therefore different in each case from the others. The lack of suitable page headings makes reference in many cases more inconvenient.

In justice to those students who transfer from one college to another either in the same or in different universities, it is important that the description of each course of instruction should be expressed in such definite technical terms and with such completeness as to its content and the methods of instruction that the head of a corresponding department in another institution may be enabled to form a fair estimate of its character and value in comparison with the course given in his own department. It is not to be expected that courses shall be identical in different institutions in widely separated parts of the country with varying needs and conditions.

The primary object of this paper, however, is to consider the manner in which this information is printed in the several catalogues with the hope that unnecessary differences may be gradually eliminated and that such a general arrangement may be finally adopted as will greatly facilitate references to the catalogs by prospective students as well as those in residence, and by members of the instructing staff in any college.

It is gratifying that some universities having a large number of colleges are publishing their announcements of courses, etc., in separate small pamphlets, so that it is no longer necessary to examine a bulky and complicated catalog to obtain the complete data desired. It also proves doubtless to be an economical arrangement with respect to the cost of printing and postage.

The term "course of study" is used in this paper to designate a list of those courses of instruction with their assigned hours and credits, arranged by years and terms or semesters, and which are required for any given academic degree, or adapted to the special needs of some group of students in case no degree is given. To indicate the marked differences in the statements of courses of study the following abstracts are presented, all of them relating to courses for civil engineering.

The following table includes a fairly representative list statements relating to the subject of mechanics, and the accompanying details.

TYPES OF RECORDS IN COURSES OF STUDY.

Junior Year, 2d Term. Course 161. Strength of Materials	17 weeks, 8 hours per week.				
Second Year, 2d Semester. Theoretical and Appied Mechanics	Subject No. 160	Hours per Week. Class. 4	Lab. 0	Prep. 6	Units. 10
Junior Year, 1st Half Year. Resistance of Materials (Civil 81), p. 81.	3 [credits].				
Junior Year, 2d Term. Page 101. Exp. Eng. 6. Analytic Mechanics	Hours per Week. Class. 4	Lab. 0	Equivalent. 10		

	Weekly Periods.	Hours of Credit.	Credit Hours.
Junior Year, ——. Engineering Mechanics, 49 (50)	2 and 3	2	5
Junior Year, Winter Term. Applied Mechanics, II C. E.	6	[Rec. Hrs.] [Lab. Hrs.] (4 — 4)	
Junior Year, 1st Semester. Math. 20 [= Analytical Mechanics]	Lectures. 3	Laboratory. 0	

In courses of study the years are designated as:

Freshman; Sophomore; Junior; Senior.

First; Second; Third; Fourth.

Fourth; Third; Second; First.

Freshman; Junior; Senior (in a 3-year course).

The terms of the academic year are named as follows:

First Semester; Second Semester.

First Term; Second Term.

First Half-year; Second Half-year.

First Term; Second Term; Third Term.

Fall Term; Winter Term; Spring Term.

The subject of mechanics is indicated by the following terms:

Analytic Mechanics; Analytical Mechanics; Theoretical Mechanics; Technical Mechanics; Engineering Mechanics; Mechanics of Engineering; Structural Mechanics; Mechanics; Applied Mechanics; Theoretical and Applied Mechanics; Analytical and Applied Mechanics; Mechanics of Materials; Strength of Materials; Resistance of Materials; Strength and Resistance of Materials; Materials of Engineering; Elements of Mechanics; Elementary Mechanics; Elementary Strength of Materials.

The following items are given in the courses of study:

Official title of course of instruction; descriptive name of course; duration of course; lecture hours per week; recitation hours per week; laboratory hours per week; actual hours per week; number of exercises; number of weekly periods; units; equivalents; credits; credit hours; reference to page where the course of instruction is described; and occasionally the days and hours of the schedule, as well as the names of in-

structors. The official designation of courses are given either with or without the names of departments by which they are given, and with arabic or roman numerals. The order of the items referred to in this paragraph seems to include the largest possible variety in arrangement.

Apart from the record of the courses of instruction in mechanics, it is interesting to note that they are given under the direction of the following departments: Engineering; Civil Engineering; Mechanical Engineering; Electrical Engineering; Experimental Engineering; Structural Engineering; Mechanics (under a variety of names like theoretical and applied mechanics, mechanics of engineering, etc.), Physics and Mathematics.

When the 3-term system is used the credit hours must be reduced one third to make them equivalent to those of the 2-term system. In a number of cases where the 2-term system is employed the credit hours are not equivalent since in some the total number of hours for a term is 16 to 18 and in others $24\frac{1}{2}$ to 28. In one case (No. 29) the total number is 46 hours but these are actual hours, including time allowed for lesson preparation and for writing reports.

The differences in requirements in the fundamental courses of mechanics and hydraulics are indicated in the following tables, which were compiled from the catalogues dated 1912–13, containing the announcements for 1913–14, for most of the colleges in the United States which give courses in engineering. In the table for mechanics it was not the intention to include the topic of mechanics which usually forms a part of the general course in physics. In the table for hydraulics it was not intended to include applied hydraulics usually called hydraulic engineering, nor laboratory work of an advanced character beyond that which frequently accompanies or follows the recitation or lecture course on theoretical hydraulics and hydraulic motors in order to illustrate the theory. The tables may contain some errors since the limits of each course were not always clearly defined. The titles in-

serted which are enclosed by brackets were taken from the corresponding descriptions of courses.

The courses of instruction are usually grouped by departments, and arranged in regular numerical order in each group. The following extracts illustrate the range of diversity in the description of courses of instruction. Some typical descriptions of courses in mechanics and in hydraulics are given below.

University of Florida.

Names of Courses.	Nature of Work.	Hrs. per Week. Semester. 1st.	2d.
Draw. III.	Mech. Draw. to scale (3 actual hrs.) ...	1½	1½
Elect. Eng. Ia.	Elem. general course	3	0
Graphic Statics I.	Elem. graphics; Roofs (5 actual hrs.) ..	0	2½
Hydraulics I.	Elements of Hydrs.	0	3
Maths. IV.	Solid Analy. Geom. & Calc.	2	2
Mechanics I.	Mechanism (4 actual hrs.)	2	2
Mechanics II.	Analy. Mechanics	4	0
Mechanics III.	Strength of Materials	0	4
Munic. Eng. I.	Roads and Pavements	2	0
Railroads II.	Prelim. & Final Location (6 actual hrs.)	3	0
Spanish II.		3	3
Surveying III.	Higher Surveying	0	2½
		20½	20½

Catholic University.

THIRD YEAR.

First Half-year. Subject.	Half-Credits.	Second Half-year. Subject.	Half-Credits.
Mathematics V.	4	Mechanics III.	4
Calculus, adv. course.		Applied Mechanics.	
Mechanics III.	4	Astronomy II.	3
Applied Mechanics.		Practical Astron.	
Astronomy I.	3	Civil Engineering II.	2
General Astronomy.		Higher Surveying.	
Civil Engineering II.	2	Civil Engineering IV.	4
Higher Surveying.		Railroad Surveying.	
Civil Engineering III.	2	Civil Engineering V.	2
Highway Engineering.		Materials of Construct.	
Civil Engineering IV.	4	Civil Engineering VI.	3
Railroad Surveying.		Theory of Struct. 1st course.	
Philosophy I.	3	Civil Engineering X.	4
Introduction to Philos.		Theoretical Hydraulics.	

Religion III. 1				Philosophy I. 3		
Comparative Religion.				Introduction to Philos.		
				Religion III. 1		
				Comparative Religion.		
				Total credits for the year 24½		

Delaware College.

SENIOR YEAR.

First Term.	*P.	H.	C.	Second Term.	P.	H.	C.
Geology, 2	45	3	3	Civil Eng., 12	57	3	3
Civil Eng., 3	55	4	4	Civil Eng., 3	55	4	4
Civil Eng., 4	55	4	4	Civil Eng., 4	55	4	4
Civil Eng., 5	56	2	2	Civil Eng., 5	55	2	2
Civil Eng., 9*a*	56	4	3	Civil Eng., 9*a*, *b*	56	4	3
Civil Eng., 13	57	2	1	Civil Eng., 13	57	2	1
Civil Eng., 14	57			Civil Eng., 14	57		
Military Science, 4 ...	62	3	2	Military Science, 4 ...	62	3	2
Options, one to be taken				Options, one to be taken			
Civil Eng., 7*a*, *b*, *c* ...	56	5	3.5	Civil Eng., 7*a*, *b*, *c* ...	56	5	3.5
Civil Eng., 11	56	3	3	Civil Eng., 10	56	3	3
			26.5				25.5

University of Nevada.

JUNIOR YEAR.

First Semester.	Lab.	Lec.	Second Semester.	Lab.	Lec.
Civil Eng., 21	2	2	Civil Eng., 21	2	2
Civil Eng., 29	2		Civil Eng., 26		3
Mathematics, 20		3	Civil Eng., 27	1	2
Mathematics, 21		2	Mathematics, 20		3
Electrical Eng. 21 or Geology 21		3	Mathematics, 21		2
Elective		4	Elective		3
Total		18	Total		18

Summer School of Mine Surveying (Civil Eng., 32), 4 weeks, 3 credits.

Louisiana State University.

JUNIOR CLASS.

	Hours a Week. 1st Term.	2d Term.	Number of Course. 1st Term.	2d Term.
Astronomy	3	—	1	—
Civil Engineering	4	4	3	4
Civil Engineering	3	3	9	10

* The letters represent pages, hours, and credits, respectively.

Civil Engineering	6	6	9	10
Mathematics	3	3	9	10
Mechanical Eng.		3	—	12
Physics	2	2	5	6
Physics	2	2	9	10
Physics	2	2	7	8
	25	25		

Cornell University (slightly modified).

JUNIOR YEAR.

Page.		Course No.	1st Term.	2d Term.
17	Political Economy	H. & P. S. 51	3	3
26	Railroads	C. E. 60	4	4
28	Bridges	C. E. 71	4	4
21	Hydraulics	C. E. 23	3	3
25	Municipal Engineering	C. E. 52	—	3
20	Survey Computations and Mapping	C. E. 14	4	—
			18	17

REQUIRED COURSES IN MECHANICS.

No. of Col.	Year.	Term.	Statement in Course of Study for Civil Engineering.
1	Junior	2d*	Mechanics of Materials (Engineering 110) 5
		3	Mechanics of Materials (Engineering 110) 5
5			
6	Third	1	Civil Engineering 7. Analytical Mechanics, 3 class hrs. Civil Engineering 8. Mechanics of Materials, 2 class hrs.
7	Junior	1	Course 161. Applied Mechanics, Strength of Materials, 17 weeks, 8 hrs. per wk.
		2	Course 161. Strength of Materials, 17 weeks, 8 hrs. per wk.
8	Second	2	Theoretical and Applied Mechanics, Course 160, 4 class hrs. [See notes.]
		3	Strength of Materials, Course 162, 4 class hrs. for half term. [See notes.]
10	———	1	2*a*. Mechanics of Materials 5
11	Sophomore	2	Technical Mechanics (C. E. 5*a*) 2
	Junior	1	Technical Mechanics (C. E. 5*b*) 3
		2	Applied Mechanics (C. E. 6) 3

* Three terms per year.

Required Courses in Mechanics (*continued*).

12	Junior	1, 2	Mechanics (Mathematics 12), p. 69, 3 and 3
		1, 2	Resistance of Materials (Civil 81), p. 81 ..... 3 and 2
14	Senior	1, 2	Mechanics, C. E. 53.. 3 and 1 recitations.
	[Third]	1, 2	Strength of Materials, M. E. 60, 2 rec. + 2 draw. or lab. each term.
15	Senior	1, 2	[Mechanics of Materials], Civ. Eng. 4, p. 55 ..... 4 and 4
16	Second	1, 2	Mechanics I, Theoretical Mechanics, 3 and 3 half-credits.
	Third	1, 2	Mechanics III, Applied Mechanics, 4 and 4 half-credits.
17	Junior	—	Applied Math., 20, 22, Mechanics; Mechanics of Materials ..... —
19	Junior	1	Mechanics II, Analytical Mechanics, p. 162 4
		2	Mechanics III, Strength of Materials, p. 162 4
	Senior	1	Mechanics IV, Analytic Mechanics, p. 162 4
20	Senior	—	Civ. Eng. C 1–2–3–4 [Applied Mechanics, Hydraulics, Bridges, Arches and Reinforced Concrete, Water Supply, and Sewerage] ..... credits 6
21	Junior	2	p. 101, Exp. Eng. 6, Analytic Mechanics, 4 class hrs.
			p. 125, Mech. Eng. 12, Mechanics of Materials ..... 3 class hrs.
			p. 125, Mech. Eng. 13, Mechanics of Materials ..... 2 class hrs.
23	Junior	1, 2	Phys. 105, 106, Analytic Mechanics, 3 and 3
		2	C. E. 24, Mechanics of Engineering ... 4
24	Sophomore	1, 2	Analytical Mechanics, p. 68 .... 4 and 4
		2	Strength of Materials, p. 68 4
26	Sophomore	2	Analytic Mechanics, C. E. 20 3
	Junior	1	Mechanics of Materials, C. E. 21 4
27	Fourth	—	Structural Mechanics, Engineering D 3. 3
28	Second	2	Theor. and Appl. Mech. 7, Analytic Mechanics 3

Required Courses in Mechanics (*continued*).

	Third	1	Theor. and Appl. Mech. 8, Analytic Mechanics 2½
		1	Theor. and Appl. Mech. 9, Resistance of Materials 3½
29	Junior	1, 2	Applied Mechanics 1, 2; p. 101, p. 119 [4 credits] points ..... 10 and 10
30	Junior	1, 2	Analytic Mechanics, p. 132, Course IX, 5 and 2
		2	Mechanics of Materials, p. 132, Course X 3
31	Junior	1, 2	III, VI, Analytical Mechanics .. 3 and 3
		2	IX, Strength of Materials 1
32	Senior	1	VI, Applied Mechanics 3
33	Junior	[1, 2]	Engineering Mechanics (49, 50), 2 and 3 weekly periods. [See notes.] [Mechanics] Materials of Engineering (Engin. 58), 5 weekly periods. [See notes.]
35	Junior	1	Mechanics 50, Mechanics 5
		2	Mechanics 51, Strength of Materials .. 4
36	Junior	Fall*	Applied Mechanics I, 4 rec. hrs., 2 lab. hrs. 5
		Winter	Applied Mechanics II, C. E., 4 rec. hrs., 4 lab. hrs. 6
37	Sophomore	1*	Appl. Mech. and Hyd. I, p. 137, Elementary Strength of Materials, credits, 2.0
		1	Appl. Mech. and Hyd. II, p. 138, Elementary Mechanics 0.8
	Junior	1	Appl. Mech. and Hyd. III, p. 138, Advanced Strength of Materials 2.0
		2, 3	Appl. Mech. and Hyd. IV, p. 138, Analytical Mechanics 3.0
38	Junior	2	Mech. Eng. 12 [Mechanics of Materials] 3
39	Junior	1	M. & M. 33, Analytical Mechanics 3
		1, 2	M. & M. 31, 32, Mechanics of Materials and Graphics ..... 4 and 3
40	Junior	1, 2	Mechanics, 5, 6 ..... 5 and 5
43	Second	2	Applied Mechanics (60) [Statics, Stresses in Frames, Dynamics] ... 45 exercises
	Third	1	Applied Mechanics (66) [Strength of Materials] ..... 60 exercises

* Three terms per year.

Required Courses in Mechanics (*continued*).

45	———	1 or 2	Eng. Mech. 1, Kinematics and Statics, Elements of Graphical Statics 4
		1 or 2	Eng. Mech. 2, Strength of Materials... 3
		1 or 2	Eng. Mech. 3, Dynamics 3
46	Junior	Fall*	C. E. 4*a*, Mechanics of Engineering... 5
		Winter	C. E. 4*b*, Mechanics of Engineering ... 5
		Spring	C. E. 4*c*, Strength of Materials 5
47	Junior	1	Math. and Mech. 5, Calculus and Mechanics 3
		2	Math. and Mech. 6, Analytical Mechanics 3
	Senior	1	Math. and Mech. 7, Strength and Resistance of Materials 4
50	———	—	103. Mechanics of Engineering 4
52	Sophomore	2	Statics. Mech. 1 ..... recitations 3
	Junior	1	Stresses and Strains. Mech. 2 3
		2	Dynamics. Mech. 3 4
53	Junior	1, 2	Mechanics (C. E. 5) ..... 4 and 4
54	Sophomore	2	Mechanics, C 20 3
	Junior	1	Mechanics, C 21 3
		1, 2	Applied Mechanics, C 22, C 23.. 3 and 3
55	Second	2	Applied Mechanics (Theoretical and Applied), 14 3
	Third	1	Applied Mechanics (Mechanics of Materials), 15 3
56	Junior	1, 2	Math. 20 [Analytical Mechanics], lectures, 3 and 3
		1, 2	Math. 21 [Mechanics of Materials], lectures, 2 and 2
57	Junior	1	Mechanics 254 [Calculus and Mechanics] 5
		2	Mechanics 255 4
		2	Mechanics of Materials 309 3
58	Sophomore	2	Math. 206, Analytical Mechanics 2
	Junior	1	Math. 305, 306, Analytical Mechanics. 3
		2	Civ. Eng. 302, Mechanics of Materials. 4
60	Third	1, 2	[Phys. and E. E.] II 4, Mechanics, class hours, 4 and 4
		2	[C. E.] IV 6, Strength of Materials, class hours, 5
61	Junior	1, 2	311, 312, Applied Mechanics ... 5 and 3

* Three terms per year.

Required Courses in Mechanics (*continued*).

62	Sophomore	1	Elements of Mechanics, 30 2
	Junior	1	Analytical and Applied Mechanics, 99. 5
		2	Mechanics of Materials, 31 3
63	Sophomore	1, 2	C. E. 20, Mechanics of Engineering, 5 and 5
64	Second	2	p. 109, Mech. 102, Analytical Mechanics, 5 class hrs.
	Third	1	p. 77, Civ. Eng. 53, Resistance of Materials ..... 5 class hrs., 3 lab. hrs.
		2	p. 77, Civ. Eng. 54, Resistance of Materials (Problems) ..... 3 lab. hrs.
65	Sophomore	2	Mechanics, 94 3
	Junior	1	Mechanics of Materials, 95 3
		1	Analytical Mechanics, 96 2
66	Sophomore	2	M. S. 2, Theoretical and Applied Mechanics ..... lecture hrs. 5
	Junior	1	M. S. 3, Mechanics of Materials, lecture hrs. 5
67	Sophomore	2	Theoretical Mechanics (Mech. 1) 2
	Junior	1	Theoretical Mechanics (Mech. 4) 2
		1	Applied Mechanics (Mech. 5) 3
68	Second	1, 2	Mechanics (Math. VII, VIII).. 3 and 3
	Third	1	Mechanics (S. D. I) 5
69	Second	2	Applied Mechanics (60) [Statics, Stresses, in Frames, Dynamics] ... 45 exercises
	Third	1	Applied Mechanics (66) [Strength of Materials] ..... 60 exercises
70	Sophomore	1, 2	Math. 3A, Elementary Mechanics. 2 and 2
	Junior	1, 2	Math. 4, Calculus and Analytical Mechanics ..... 3 and 3
	Senior	1, 2	Math. 8, Mechanics of Materials. 3 and 3
71	Junior	1, 2, 3*	Mechanics, 204 ..... 3, 3 and 3
	Senior	1	Mechanics of Materials, 215 3
72	Junior	Fall*	M. E. 30 [Analytical Mechanics] 5
		Spring	M. E. 31 [Mechanics of Materials] ... 5
73	Junior	—	Mechanics ([M. E.] 61, 62) 8
75	Sophomore	2	Mechanics of Engineering, Appl. Math. 2 4
	Junior	1, 2	Dynamics, Appl. Math. 3 ..... 2½ and 3
76	Sophomore	2	Applied Mechanics, Appl. Mech. 21, 17 weeks, 4 hrs. per week

* Three terms per year.

Required Courses in Mechanics (*continued*).

	Junior	1	Applied Mechanics, Appl. Mech. 22, 17 weeks, 5 hrs. per week
79	Third	1	Mech. 51 [Mechanics] 4
		1	Mech. 52 [Applied Mechanics] 2
		2	Mech. 53 [Mechanics of Materials] .. 4
80	Junior	Winter*	Civ. Eng. 10*a* (Applied Mechanics) ... 5
		Spring	Civ. Eng. 10*b* (Applied Mechanics) ... 4
	Senior	Fall	Civ. Eng. 18 (Strength of Materials). 3
81	Junior	1	Statics and Dynamics (M. E. 200) ... 4
		2	Strength of Materials (M. E. 201) ... 2
81	Junior	1, 2	Math. 17 (Analytical Mechanics) 3 and 3
		2	Struct. Eng. 42 (Strength of Materials), 4
83	2d [Jun.]	Winter*	Mechanics, Rational ..... —
		Spring	Mechanics of Materials ..... —
	1st [Sen.]	Fall	Mechanics of Materials ..... —
84	Sophomore	3*	Applied Mechanics, 621 4
	Junior	1	Applied Mechanics, 622 4
		1, 2	Mechanics of Materials, 623, 624. 4 and 4
85	Junior	—	C. E. 5, Mechanics, Statics ... periods, 3
86	Junior	1*	Mechanics ..... [5]
		1	Strength of Materials ..... [5]
87	Sophomore	1, 2	Mechanics [Math.] 93 ..... 3 and 2
	Junior	1	Mechanics and Strength of Materials [Math.] 94 2
		1	Analytical Mechanics [Math.] 94 2
88	———	1, 2	(413) Strength of Materials ... 4 and 4
89	Sophomore	2	Analytic Mechanics, p. 254, Phys. 20.. 3
	Junior	1	Mechanics of Materials, p. 181, C. E. 40, 5
90	Sophomore	Summer*	Mech. 1 [Analytical Mechanics], p. 164, 5
	Junior	F. or W.	Mech. 2 [Mechanics of Materials], p. 164 5
91	Sophomore	2	Analytic Mechanics, 147 2
	Junior	1	Strength of Materials, 172 4
92	Sophomore	2	Mchs. 1, Elementary Mechanics 3
	Junior	1	Mchs. 2, Applied Mechanics 5
93	Junior	1, 2	p. 128, Mech. Eng. 215, Mechanics of
		2	Materials ..... class hrs., 3
			Math. 257, Analytic Mechanics, class hrs., 3
94	Junior	1, 2	Applied Mechanics (Mech. Eng. X) 5 and 1½

* Three terms per year.

Required Courses in Mechanics (*continued*).

95	Junior	1, 2	Mechanics 1, 2 [Mechanics of Solids], —
96	Junior	2, 3*	Mechanics ([M. E.] 211) ..... 3 and 2
	Senior	1	Mechanics of Engineering ([M. E.] 212) 2
97	Second	1, 2	Mech. 1, Elementary Mechanics, Elementary Strength of Materials ..... [?] 6
	Third	—	Mech. 2, Theoretical Mechanics ... [?] 6
		1	Mech. 3, Strength of Materials ... [?] 6
98	Junior	2	Analytic Mechanics, *a*, Math 14 3
		2	Mechanics of Materials, *a*, M. E., 16.. 5
99	Junior	1, 2	Mechanics of Engineering ..... 3 and 3
100	Junior	1, 2	Theoretical Mechanics, 5, 6 .... 3 and 3
	Senior	1	Theoretical Mechanics, 7 3
102	Sophomore	1	Mechanics 1 [Statics with Application to Stresses] ..... recitations, 3
		2	Mechanics 2 [Mechanics of Materials], recitations, 3
	Junior	1	Mechanics 3 [Dynamics], 3 recitations, 3 hrs. practice
104	Sophomore	Spring*	Mechanics (C. E. 1265) 3
	Junior	Fall	Applied Mechanics (C. E. 32) 3
		Winter	Applied Mechanics (C. E. 32) 3
105	Junior	1	Civ. Eng. 6, Mechanics of Materials... 4
106	Junior	1, 2	Engineering 3 (Mechanics) .... 4 and 4
107	Junior	A	Applied Mechanics [Theoretical Mechanics] 4
		B	Applied Mechanics [Mechanics of Materials 4
108	Sophomore	1, 2	Mechanics [Technical Mechanics], 2 and 3
	Junior	1, 2	Mechanics of Materials, 4 ..... 3 and 3
109	Third	2, 3*	Mechanics of Engineering (365), 3 and 6
	Fourth	1, 2*	Mechanics of Materials (366).. 3 and 3
110	Junior	Fall*	Mechanics. Statics and Elementary Dynamics (500) 3
		Winter	Mechanics. Dynamics of a Particle (501) 3
		Spring	Mechanics. Dynamics of a Rigid Body (502) 3
	Senior	Fall	Mechanics. Strength of Materials (503), 3
111	2d [Jun.]	1	Analytical Mechanics, Mech. of Eng. I, 6

* Three terms per year.

Required Courses in Mechanics (*continued*).

		2	Mechanics of Materials, Mech. of Eng. II 3
113	Junior	1	Theoretical Mechanics (C. E. 9) 5
		2	Applied Mechanics (C. E. 29) 4
114	Junior	1, 2	Civ. Eng. 41, 42 (Mechanics)... 4 and 3
117	Second	2	Statics (Engineering 70) 3
	Third	1	Mechanics of Materials (Engineering 71) 4
		2	Kinetics (Engineering 72) 3
118	Second	1	Mechanics 1. Statics 3
		1, 2	Mechanics 2, 3. Mechanics of Materials, 2 and 3
		2	Mechanics 4. Dynamics 2
120	Junior	1	Math. V (Theoretical Mechanics) 5
		2	Math. VI (Applied Mechanics) 5

Notes.—No. 8, see types of records following the next table, second entry; No. 33, see types of records, fifth entry.

REQUIRED COURSES IN HYDRAULICS.

1	Senior	2*	Theoretical Hydraulics (Eng. 116) ... 5
		3	Practical Hydraulics (Eng. 117) 4
5			
6	Third	2	C. E. 9. Hydraulics ..... class hrs., 3
7	Junior	2	Hydraulics (306), 17 weeks, 5hrs. per week
8	Third	1	Hydraulics, 230, (see notes) class hrs., 4
		2	Hydraulic Motors, 232, (see notes) class hrs., 2
		2	Hydraulics Laboratory, 231.. lab. hrs., 3
			Hydraulic Machinery, 233.. lab. hrs., 3
10	———	2	3. Hydraulics, *a*. Hydrostatics and Hydraulics 3
	———	1	3. Hydraulics, *b*. Hydraulic Motors .. 3
11	Senior	1	Hydraulics (C. E. 7) 2
12	Junior	1	Hydraulics (Civil 41), p. 80 2
		1	Hydraulic Laboratory (Civil 42), p. 80, 1
14	Sen. [3d]	2	Hydraulics, C. E. 54 ..... recitations, 2
15	Senior	1, 2	Hydromechanics 3, p. 55 ..... 4 and 4
16	Third	2	Civ. Eng. X, Theoretical Hydraulics, half-credits, 4

* Three terms per year.

Required Courses in Hydraulics (*continued*).

17	Senior	—	Appl. Math. 21. Hydraulics ..... —
19	Junior	2	Hydraulics I. Elements of Hydraulics, p. 157 3
20	Senior	—	Civ. Eng. C 1–2–3–4 [Applied Mechanics; Hydraulics; Bridges, Arches and Reinforced Concrete; Water Supply and Sewerage] ..... credits, 6
21	Junior	1	Page 67, Civ. Eng. 15. Hydraulics, class hrs., 3
		2	Page 104, Exp. Eng. 18. Hydraulic Laboratory ..... lab. hrs., 4
23	Junior	2	C. E. 28. Hydraulics ..... credits, 3
24	Junior	1	Hydraulics, p. 69 5
26	Junior	2	Hydraulics, C. E. 16 2
27	Fifth	1	[Hydraulics is probably included in Hydraulic Engineering.]
28	Third	2	Theor. and Appl. Mech. 10. Hydraulics, 3
29	Junior	2	Hydraulics, 42, p. 118 ..... points, 5
		2	Hydraulic Laboratory, 59, p. 119, points, 3
30	Senior	1, 1	Hydromechanics, XVI, p. 136 .. 3 and 3
31	Senior	1	VII, Hydraulics 2
32			
33	Junior	—	Hydraulics and Hydraulic Machinery (Engin. 31) 5
35	Senior	1	Civ. Eng. 68. Hydraulics 3
		1	Civ. Eng. 60. Hydraulic Laboratory.. 1
36	Junior	Spring*	Hydraulics (3—2) 4
37	Junior	1*	Appl. Mech. and Hyd. V. Hydraulics, credit, 0.8
38	Senior	1, 2	Civil Engineering 11, 20 [Hydraulics], 2 and 2
39	Senior	1	Hy. E. 41. Hydraulics 4
40	Junior	2	Civil Engineering 10 [Hydraulics] ... 3
43	Fourth	1	Theoretical Hydraulics (330), 45 exercises
		2	Hydraulic Laboratory (342), 15 exercises
45	———	1 or 2	Civ. Eng. 11. Hydraulics 2
		1 or 2	Eng. Mech. 4. Hydromechanics 2
46	Senior	Fall*	C. E. 5. Hydraulics 5
			C. E. 5*a*. Hydraulic Laboratory..... 2
47	Senior	2	Math. and Mech. 8. Hydraulics 4

* Three terms per year.

Required Courses in Hydraulics (*continued*).

52 Junior	2	Hydraulics, Civ. Eng. 44.. recitations, 3
53 Junior	1	Hydraulics (C. E. 8) 3
54 Junior	2	Hydraulics, M. 50 3
	2	Hydraulic Laboratory, M. 52 1
55 Third	1	Civil Engineering (Hydraulics) 11 ... 2
56 Senior	1	Civ. Eng. 28 [Hydraulics] .. lectures, 2
57 Senior	1	Hydraulic Engineering, 313 3
	2	Hydraulic Laboratory, 320 1
58 Senior	1	Civ. Eng. 405. Hydraulics 2
60 Fourth	1	VIII, 12. Hydraulics ..... class hrs., 3
61 Junior	2	356. Hydraulics 3
62 Junior	1	Theoretical Hydraulics, 38 3
63 Junior	1, 2	C. E. 23. Hydraulics ..... 3 and 3
64 Fourth	1	Page 79, Civ. Eng. 75. Hydraulics, class hrs., 4
	1	Page 95, M. E. 63. Hydraulics Laboratory ..... lab. hrs., 3
65 Senior	1	Hydraulics, 33 2
66 Senior	1	M. S. 9. Hydraulics .... lecture hrs., 2
	2	M. S. 9. Hydraulic Motors and Machinery ..... lecture hrs., 2
67 Junior	2	Hydraulics (Mechanics 3) 3
68 Third	1, 2	Hydraulics (H. I.) ..... 3 and 3
69 Fourth	—	Hydraulics; Hydraulic Laboratory; Aerodynamics ..... —
70 Senior	1, 2	Math. 7A. Hydraulics and Sanitary Engineering ..... 3 and 3
71 Senior	2, 3*	Hyrdaulics 216 ..... 2 and 2
72 Junior	Winter*	C. E. 8. [Hydraulics] 5
73 Senior	—	Hydraulics (M. E. 67) 2
	—	Hydraulics (M. E. X. 44) [Hydraulic Laboratory] 2
75 Junior	1	Hydraulics, C. E. 13 3
76 Junior	2	Hydraulics, Appl. Mech. 25, 17 weeks, 4 hrs. per week
Senior	1	Hydraulic Laboratory, Appl. Mech. 26, 8 weeks, 3 hrs. per week
77 Third	2	Mechanics (102), Kinetics and Hydraulics 5
79 Third	2	Mech. 55 [Theoretical Hydraulics] ... 3

* Three terms per year.

Required Courses in Hydraulics (*continued*).

80	Senior	Fall*	Civ. Eng. 11 (Hydraulics), 3 class hrs., 2 lab. hrs.
81	Junior	2	Hydraulics (M. E. 202) 2
		2	Hydraulic Laboratory (Exp. Eng. 141), 1
82	Senior	1	Hyd. Eng. 61 (Hydraulics) 4
83	1st [Sen.]	Fall*	Hydraulics ..... —
84	Junior	3*	Hydraulics, 661 3
		3	Hydraulic Laboratory, 663 1
	Senior	1	Hydraulics, 662 3
		1	Hydraulic Field Work, 664, 2 afternoons
85	Junior	2	C. E. 10. Hydraulics ..... periods 3
86	Senior	2*	Hydraulic Motors [Hydraulics, etc.], [5]
87	Senior	1	Hydraulics, 32 3
88	———	1, 2	Hydraulics ..... 2 and 2
89	Junior	1	Hydromechanics, p. 180, C. E. 25 3
		1	Hydraulic Testing, p. 181, C. E. 26 .. 3
90	Junior	Spr. or Sum.*	San. Eng. 1, p. 181 [Hydromechanics and Hydraulics] 4
		Spr. or Sum.*	San. Eng. 2, p. 181 [Hydraulic Laboratory] ..... 3 lab. hrs., 1
91	Junior	2	Hydraulics, 177 3
		2	Hydraulic Laboratory, 187 1
92	Junior	1	Hyd. 1. Hydraulics 2
		2	Hyd. 3. Hydraulic Laboratory 1
93	Senior	1	Page 129, Engineering 225. Hydraulics, class hrs., 3
94	Junior	2	Hydraulics (Mech. Eng. XI) ..... $3\frac{1}{3}$
95	Senior	1	Mechanics 3 [Mechanics of Fluids].. —
		2	Mechanics 4 [Applied Hydraulics = Hydraulic Motors] ..... —
97	Fourth	1	Hydraulics and Water Power .... [?] 3
98	Junior	1	Hydraulics, *a*, Civ. Eng. 5 3
102	Junior	2	Mechanics 4 [Hydraulics] 3
104	Junior	Spring*	Applied Mechanics (C. E. 32) [includes Hydraulics] 3
		Spring*	Hydraulic Laboratory (C. E. 128) 1
105	Junior	1, 2	Civ. Eng. 7. Hydraulics ..... 2 and 2
106	Senior	1	Engineering 6 (Hydraulics) 4
		2	Engineering 11 (Hydraulic Laboratory), 1
107	Senior	1, 2	Hydraulics ..... 3 and 1
		2	Hydraulic Laboratory 1
108	Junior	2	Hydraulics 2

* Three terms per year.

Required Courses in Hydraulics (*continued*).

109	Fourth	3*	Hydraulics (372) 3
110	Junior	Winter*	Mechanics. Hydrostatics and Hydraulics (504) 3
		Spring	Mechanics. Hydraulic Motors and Pumps (505) 3
		Spring	Mechanical Laboratory. Hydraulic Laboratory (555) 1
111	1st [Sen.]	2	Hydraulics, Civ. Eng. IV 3
113	Junior	1	Hydraulics (C. E. 13) 5
		2	Hydraulic Laboratory (C. E. 26) 2
114	Junior	2	Civ. Eng. 50 (Hydraulics) 4
117	Third	2	Hydraulics (Engineering 73) 2
118	Third	1	Hyd. and San. Eng. 1. Hydraulics... 3
120	Junior	2	C. E. VIII (Hydraulics) 3

James Millikin University.

20. ANALYTIC MECHANICS.—Prerequisite, Calculus, 7. This course consists of the study of those problems of mechanics which are the basis of all work in engineering design. Text-book: Hancock's Applied Mechanics for Engineers. (3) 3.

University of Illinois.

7, 8. ANALYTICAL MECHANICS.—The mechanics of engineering rather than that of astronomy and physics: Fundamental concepts; equilibrium and motion; engineering problems; statement of conditions and use of data. (The work begins in the second semester; in the first semester of the following year it is given concurrently with Theoretical and Applied Mechanics 9.) Maurer's Technical Mechanics. II; (3); I; (2½).

Asst. Prof. Enger, Mr. Noerenberg, Mr. Boomsliter, Mr. Seely, Mr. Ensign, Mr. Farwell, Mr. Millard.

Prerequisite: For 7, Mathematics 7, registration in Maths. 9; for 8, Maths. 0. Theoretical and Applied Mechanics 7.

Purdue University.

1. APPLIED MECHANICS.—First semester.

Four recitation hours per week. Required of Juniors in Engineering. Must be preceeded by Math. 4.

Precedes Applied Mechanics 2 and 3; Civil Engineering 11, 21, 33 and 34; Mechanical Engineering 64, 65, 66, 67, 68 and 69; and precedes or

* Three terms per year.

accompanies Civil Engineering 31; Mechanical Engineering 63, 72 and 73; accompanies Mechanical Eng. 61, 62.

This course begins with a study of the general principles of equilibrium, and their applications to jointed frames and machines. It then treats rectilinear, curvilinear and harmonic motions; the relativity of motions; force, mass and acceleration. This is followed by a study of physical properties of the common engineering materials; the stresses and corresponding deformations of these materials in tension, compression, shear; the principles underlying the investigation and design of pipes and cylinders carrying internal fluid pressures, riveted joints, beams and columns, in connection with which the center of gravity and moment of inertia of areas are studied. The strength and elastic properties of engineering materials as shown by actual tests, as well as familiarizing the student with the structural shapes as given in handbooks of the various steel companies, are given special attention. The solution by the student of a large number of practical numerical problems is an important feature of the course.

Profs. Dukes and Poorman; Messrs. Lawrence and Hudgins.

2. APPLIED MECHANICS.—Second Semester.

Four recitation hours per week. Required of Juniors in Engineering. Must be preceded by Applied Mechanics 1 and Physics 1.

Precedes C. E. 41 and 46; Mechanical Eng. 64, 65, 66, 67, 68 and 69; precedes or accompanies Mechanical Eng. 63, 72 and 73; accompanies Mechanical Eng. 61 and 62, and Civil Eng. 42.

This course continues with the study of the strength of materials in which are treated beams, columns and shafts; the kinetics of rigid bodies, including moment of inertia of masses, simple, compound, conical and torsional pendulums, centrifugal force and the balancing of machines; work and energy; impulse, momentum and impact; friction and lubrication.

Profs. Dukes and Poorman; Messrs. Lawrence and Hudgins.

State University of Iowa.

47. ENGINEERING MECHANICS. 5 hrs.

Recitations and problems in statics and kinetics. Prerequisites, Mathematics 23 (24), Physics 7 (8). Prof. Woodward.

Five two-hour periods a week.

49, (50) ENGINEERING MECHANICS. 2 and 3 hrs.

Same as 47. Prof. Woodward.

Two two-hour periods a week during first semester, and three two-hour periods a week second semester.

Massachusetts Institute of Technology.

60. APPLIED MECHANICS (Statics-stresses in Frames-Dynamics).
Profs. Johnston, Fuller, Hayward; Messrs. Smith and Holmes.
Preparation: 31 and 770, which may be taken simultaneously.

A course of three lectures (or recitations) per week in the second term of the second year for Courses I, II, VI, XI, XIII, and XIV, and in the first term of the third year for Courses III and X. The course comprises a study of statics, consisting of the general methods and applications of statics, including the determination of reactions, stresses in frames; of distributed forces, center of gravity; of moment of inertia, radius of gyration of plane areas and solids including principal axes and principal moments of inertia; of kinematics and dynamics including the equations for uniform and varying rectilinear and curvilinear motion, centrifugal force, unresisted projectile, pendulum, harmonic motion, rotation, combined rotation and translation, momentum and angular momentum, center of percussion, impact, work, power and kinetic energy.

(Required in Courses I, II, III, VI, X, XI, XIII, XIV.)

66. APPLIED MECHANICS (STRENGTH OF MATERIALS).
Profs. Johnston, Fuller, Hayward.
Preparation: 31; 60; 770.

A course of four lectures (or recitations) per week in the first term of the third year. The course comprises a study of the strength of materials as described in course 65 with additional applications to simple frames subjected to bending stresses; also a brief study of strains and the relations of the stresses on different planes.

(Required in Courses I and XI.)

University of Missouri.

103. MECHANICS OF ENGINEERING. (Prerequisite, Math. 6.) Statics, dynamics, strength of materials, hydrostatics, hydrodynamics. Lectures and recitations. (4) Mr. Defoe.

Cornell University.

20. MECHANICS OF ENGINEERING.—For sophomores in civil engineering. Throughout the year, credit five hours a term. Prerequisite mathematics, course 5. A study of the principles, and applications to engineering, of the mechanics of solids; as relating to the mutual actions, motions, pressures, strength, stiffness, and resilience of the members of structures and machines. Original problems form a prominent feature. Statics of a material point and of rigid bodies. Centers of gravity. Chains and cords. Dynamics (kinetics) of a material point. Impact. Virtual velocities. Centrifugal and centripetal forces. Pendulums. Moments of in-

ertia of plane figures and of rigid bodies. Dynamics (kinetics) of rigid bodies. Work. Power. Energy. Fly-wheels. Friction. Graphical statics of mechanism. Dynamometers. General theorem of work and energy applied to machines. Stresses and strains. Tension. Shearing. Compression. Torsion. Flexure. Elastic curves. Safe loads. Columns. Text-books; Church's Mechanics of Engineering, and Notes and Examples in Mechanics, supplemented by other printed notes and problems. Lectures and recitations, daily except S, throughout the year. Seven sections. Professor Church, Assistant Professors George and Rettger, and Messrs. Brauner and Dougherty.

Leland Stanford Jr. University.

COURSE 3. HYDRAULICS:

a. HYDROSTATICS AND HYDRAULICS.—This course treats of fluid pressure, the principles of fluid equilibrium, and the laws governing the flow of water through orifices, over weirs, in closed conduits, and in open channels. Open to students who have completed courses 2 and 3 in Applied Mathematics.

Monday, Wednesday, Friday, 9:15. 3 units, 2d semester (Hoskins).

b. HYDRAULIC MOTORS.—A discussion of the theory of the main types of turbines, including centrifugal pumps. A few lectures on the general theory of energy and on relative motion are given as an introduction to the course. Open to students who have completed course 3*a*.

Monday, Wednesday, Friday, 9:15. 3 units, 1st semester (Hoskins).

State University of Kentucky.

V. HYDRAULICS.—This course consists of text-book exercises together with the solution of numerous problems covering the principles of hydrostatics and hydrodynamic pressure, the flow of water through orifices and nozzles, over wires and through pipes and open channels, also the loss from friction and other sources. 2 hours per week, first term (Carrel).

Massachusetts Institute of Technology.

330. THEORETICAL HYDRAULICS.

Profs. Porter, Russell.

Preparation: 60.

A course of forty-five text-book exercises given in the first term of the fourth year, with the solution of numerous problems covering the principles of hydrostatic and hydrodynamic pressure, the flow of water through orifices and nozzles, over weirs, and through pipes and open channels, and the losses from friction and other sources. The student is made acquainted with the best experimental results, and the course is supple-

mented by exercises in the laboratory for both Options and in the field for Option I (courses 333 and 342). Russell's Hydraulics is used as a text-book.

(Required in Courses I, XI.)

342. HYDRAULIC LABORATORY.

Profs. Miller, Taft and assistants.

Preparation: 330.

A course of eight laboratory exercises of two hours each in the second term of the fourth year. The time is devoted to testing pumps, ejectors, pulsometers, etc., to measuring water by means of weirs, meters, nozzles and orifices; and to making efficiency tests of water wheels.

(Required in Courses I, XI.)

Michigan Agricultural College.

5. HYDRAULICS. Fall term. 5 credits.

Five recitation hours per week.

Prerequisite: Civil Eng. 4*c* and Mechanical Engineering 13*b*.

Required of seniors, Engineering course.

This subject is studied as an extension of our courses in mechanics of engineering. Particular attention is given to weir measurements, flow of water in channels and pipes, and discharge through different orifices.

5*a*. HYDRAULIC LABORATORY. Fall term. 2 credits.

Four laboratory hours per week.

Prerequisite: Civil Eng. 5 must precede or accompany.

Required of senior Civil Eng. students.

Experimental investigation and verification of formulae, determination of coefficients, and study of methods applicable in measuring the flow of water, and in testing the efficiency of hydraulic motors.

Washington University.

44. HYDRAULICS.—Hydrostatic and hydraulic theory, with the application of the principles thus developed to the flow of water through orifices, pipes, channels, etc.; the determination of water power; the measurement of velocities and discharge. Three hours a week. Second semester. Junior year.

Princeton University.

CIVIL ENG. 405. HYDRAULICS. Theory. Required of all C. E. seniors first term, 2 hours a week. Prof. Smith or Mr. Condit.

Lehigh University.

177. HYDRAULICS. Hydrostatics and theoretical hydraulics. The flow of water through orifices, weirs, tubes, pipes, and channels. Naval hydro-

mechanics. Hydraulic motors. Preparation required: 320, 321, 322, 145. Second term (3).

CONCLUSIONS.

The utmost simplicity is desirable in all statements in courses of study. The statement for each course should preferably include: No. of course; title; page reference to description; and credit hours for each term.

All details relating to each course should be given in the descriptions printed under course of instruction arranged by departments. Such a description should give as complete a list as practicable of subdivisions or topics included; the books used; the method of instruction, whether by lecture, recitation, computation, drawing, laboratory, field work, etc., and if several methods are combined the total number of exercises devoted to each should be given; the length of exercises; the term or terms in which the course is given; the prerequisite courses required for admission to the given course; the credit hours; the names of the instructors; the room; and the schedule hours unless the last two items are printed separately for the use of students in residence.

It is reasonable to expect that the publications of educational institutions should be, at least approximately, models of clearness, directness, simplicity, and truthfulness in statement; systematic in arrangement; and thoroughly adapted to the purposes for which they are intended to be used. This subject is worthy of careful consideration by the members of this Society and it is hoped that its discussion may lead to some constructive effort to improve existing conditions through the coöperation of the institutional representatives and of other organizations which are interested in the administrative affairs of colleges of engineering.